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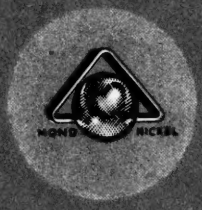

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Diffusion of Nickel in Liquid Tin

C. H. MA and R. A. SWALIN: 'A Study of Solute Diffusion in Liquid Tin.'

Acta Metallurgica, 1960, vol. 8, June, pp. 388–95.

The diffusion of aluminium, zinc, silver, copper and nickel in liquid tin was investigated, using the capillary-reservoir technique, over the temperature range 240°–480°C. The solutes investigated were present in dilute solutions ranging from 0·2 to 0·7 wt. per cent., and were chosen so as to cover a range of relative partial molal enthalpies, from large positive values to large negative values.

On the basis of the self-diffusion of tin, it was found that the ratios of D solute to D self are (within ± 15 or 20 per cent. error) 4·7, 1·9, 1·57, 1·15 and 1·10 for, respectively, aluminium, zinc, silver, copper and nickel. Diffusion coefficients of copper and nickel can, it is stated, be considered, within experimental error, to be identical with that of tin. The Stokes–Einstein and Eyring equations, which consider only the factor of atom size, do not predict accurately the relative order of diffusion coefficients amongst the solutes; they do, however, predict the order of magnitude of the diffusion constant.

Etch-Pit Method for Revealing Dislocation Sites in Nickel

R. W. GUARD: 'An Etch-Pit Method for Revealing Dislocation Sites in Nickel.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, June, pp. 573–4.

The etchant used in the etch-pit method outlined by the author was originally proposed by WENSCH (*Metal Progress*, 1950, vol. 58, pp. 735–6) as a means of revealing grain-size in nickel. The conditions under which etching can be carried out, and the feasibility of applying the technique to revelation of dislocation sites, were studied in experiments on specimens of high-purity (99·985 per cent.) nickel and commercial 'A' nickel.

The two grades, both of which contained more than 0·008 per cent. carbon, had been annealed, in nitrogen or dry hydrogen at 1100°–1200°C., to give a grain-size of 1·5 mm. in the high-purity nickel and 0·05 mm. in 'A' nickel. Tensile specimens were deformed from 0·25 to 10 per cent. at room temperature and then heated for ½ hour at temperatures in the range 400°–900°C. The specimens were sectioned longitudinally, polished electrolytically in 60 per cent. H_2SO_4, and then etched in 35 per cent. H_3PO_4 solution at 0·2–0·4v. for 30 seconds to 3 minutes. (The best method of achieving the proper voltage for etching was to increase the voltage until gas bubbles were evolved vigorously from the specimen, and then to reduce it by 10 per cent.) To ensure formation of etch pits, it was found necessary to heat the specimen at a temperature above 500°C. after deformation, a 'decoration' treatment which permits carbon to segregate to the dislocations, rendering them sensitive to etching. Some rearrangement of the dislocations is stated to occur in the as-deformed structure on heating at 500°C. and above, and the technique cannot be used to study the nature of dislocation patterns in deformed specimens. Extended etching does not change the number of pits, although the background becomes rough and the pits quite large.

The data presented indicate that the pits are reproducible, do not increase in number with extended etching, and are present in densities consistent with those observed by other techniques on deformed metals. Although the method requires decoration of the dislocation sites with carbon, it is not dependent on orientation of the surface being etched.

Kinetic Study of the Corrosion of Nickel in Sulphuric Acid

C. H. PITT and M. I. WADSWORTH: 'Kinetics of Nickel Corrosion in Sulfuric Acid.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, June, pp. 295–401.

The investigation described in the present paper has been previously reported by the authors in *U.S. Atomic Energy Commission Publn. NP*-6208, an abstract of which appeared in *Nickel Bulletin*, 1959, vol. 32, No. 2, p. 39.

Stabilization of Ti_2Ni-Type Phases by Oxygen

M. V. NEVITT: 'Stabilization of Certain Ti_2Ni-Type Phases by Oxygen.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, Apr., pp. 327–31.

The suggestion has been made by several investigators that phases of cubic $E9_3$-type structure (known as η-carbide type, double-carbide type and Ti_2Ni type) are members of a family of electron compounds. In some binary systems, Ti_2Ni-type phases occur having the formula A_2B, where A is the titanium-group element. Oxygen is known to be soluble

in two of these binary phases, Ti_2Co and Ti_2Ni, and probably also in the other phases of this kind. In other binary systems, the Ti_2Ni-type phase does not occur, but does occur in the corresponding ternary systems with oxygen. The experiments described in the paper were performed to determine whether the occurrence and composition of certain of the Ti_2Ni-type phases could be related to an electronic effect, and whether oxygen's stabilizing rôle is exerted through an influence on the electron/atom ratio. The ternary systems Ti-Mn-O, Ti-Fe-O, Ti-Co-O and Ti-Ni-O were selected as most suitable for study.

The boundaries of the Ti_2Ni-type phases were determined at one or more temperatures, and a study was made of the variation of the lattice parameter with oxygen content. Densities were calculated from the lattice parameters and compared with measured density values. The results indicate that the phase's occurrence in these systems can be correlated qualitatively with valency electron concentration, and that the rôle of oxygen is that of an electron acceptor. The lower limit of oxygen solubility appeared to be determined by the valencies of manganese, iron, cobalt and nickel, while the maximum oxygen concentration coincides with the filling of the 16(*c*) positions of the O_h^7-Fd 3m space group.

Reaction Mechanism of the Nickel-Cadmium Cell

S. U. FALK: 'Investigations on the Reaction Mechanism of the Nickel-Cadmium Cell.'

Jnl. Electrochemical Soc., 1960, vol. 107, Aug., pp. 661–7.

Although the nickel-cadmium cell has provoked the interest of many investigators, and many theories have been put forward concerning the reactions and thermodynamics of the system, opinions still differ in many essentials. In this paper, therefore, the authors publish the results of investigations carried out to establish the reaction formulae of the nickel-cadmium cell and to elucidate the reaction mechanism.

A specially constructed cell (containing one sintered electrode of the kind to be investigated, and one sintered electrode of opposite polarity) enabled X-ray-diffraction patterns to be obtained from electrodes submerged in electrolyte, and so permitted determination of the composition of the active materials during charge and discharge. The question as to whether CdO or $Cd(OH)_2$ is formed during discharge was the subject of particular attention. The secondary-discharge stage of the positive electrode was studied, and, in another phase of the programme, the emf of the nickel-cadmium cell was investigated as a function of temperature and state of charge. Six conclusions are drawn:

'(1) The main reaction of the nickel-cadmium cell on charge and discharge is

$$2\beta\text{-NiOOH} + Cd + 2H_2O \rightleftharpoons 2Ni(OH)_2 + Cd(OH)_2.$$

'(2) The secondary-discharge stage of the positive electrode is probably caused by oxygen adsorbed by $Ni(OH)_2$.

'(3) The high initial potential of the negative electrode after charge is caused by hydrogen adsorbed by Cd.

'(4) The emf of the nickel-cadmium cell is dependent on the activity of water in the electrolyte, and, consequently, on the hydroxyl ion activity. An increase of the KOH concentration from 5 to 45 per cent. results in an emf decrease of about 0·07 v.

'(5) The emf of the nickel-cadmium cell depends on the state of charge, falling continuously with lower state of charge. This effect can be attributed to the existence of a solid solution between β-NiOOH and $Ni(OH)_2$ in the positive electrode.

'(6) The dE/dT value of the nickel-cadmium cell is negative. The magnitude is −0·00018 v./°K. for sintered cells, and −0·00030 v./°K. for pocket cells.'

Use of Nickel in Chemical Plant

See abstract on p. 259.

Resistance Welding of Electronic-Component Leads to Nickel-clad Copper Wire

W. L. HUGHES: 'Resistance Welding Electronic-Component Leads to Nickel-clad Copper Wire.'

Welding Jnl., 1960, vol. 39, July, pp. 284s–91s.

Although all-welded electronic circuitry has been under consideration for several years, the difficulty of welding tinned copper, brass, copper-clad nickel-iron and gold-plated nickel-iron-cobalt electronic-component leads has hampered the realization of the project, which has never progressed much beyond the planning stage. Recent developments in high-temperature circuit techniques have, however, made available to the designer two new conductors specifically intended for use as interconnecting wires and component-lead materials operating at 500°–700°C. The conductivity of these nickel-clad ('Kulgrid') and stainless-steel-clad ('Oxalloy 28') copper wires is approximately 70 per cent. that of a copper wire. The cladding wall is about 7½ per cent. of the diameter in thickness. The wires are currently commercially available in diameters from 0·003 to 0·3 in. (0·075 to 7·5 mm.), fully cold-worked, or annealed to any desired condition up to dead soft. Both of the materials have been successfully used for experimental high-temperature circuits.

In this paper the author describes an investigation of the variables involved in production welding (using a resistance-welding technique) nickel-clad copper wire to tinned copper, to brass, to copper-clad nickel-iron wire, or to gold-plated nickel-iron-cobalt wire. Recommendations are made with respect to the optimum schedules and welding set-up for this type of work.

ELECTRODEPOSITION AND OTHER COATING METHODS

Design for Metal Finishing

INST. METAL FINISHING: 'Design for Metal Finishing.'*
Published by the Institute, 1960; 16 pp.

'In the finishing of metal articles by polishing, electroplating or painting, much time and money are wasted because of design unsuitable for the finishing processes.

'Design that takes into account not only the function of the article and its method of fabrication, but also the requirements of the finishing processes, always results in a *more serviceable* and usually a *less costly* product.

'To guide engineers and designers, the Institute of Metal Finishing outlines in this booklet the essentials of these metal-finishing processes as they relate to the design.'

In the booklet, the 'essentials of the metal-finishing processes' referred to in the above excerpt are related to design factors in three sections, an adequate idea of the scope of which may be obtained from the heads and subheads used:

(1) *Design for Polishing*

The Process: Methods of Polishing; Use of Automatic Equipment; Polishing before Fabrication; Non-Mechanical Polishing or Brightening.

Design Recommendations: Wheel Polishing; Barrel Polishing; General Considerations.

(2) *Design for Plating*

The Process: Principles; Surface Preparation; Equipment; Features of Plating; Plating Specifications.

Design Recommendations.

(3) *Design for Painting*

The Process: Nature of the Process; Surface Preparation; Paint Application.

Design Recommendations: General; Recommendations for Specific Methods.

The points raised under the above heads are illustrated or supplemented by numerous drawings.

In a postscript to the booklet it is emphasized that 'ease of finishing ought not be to sacrificed to ease of fabrication. Finishing processes often have a higher labour content than has work done in the press shop or on the assembly line. Consequently, savings in material and fabrication charges may well be dissipated by the increased cost of finishing.

'Finishing is indeed an integral part of manufacture. The same care and thought that are given to designing an article for ease of production should be given to ensuring that the article can be finished simply and effectively. If the requirements of the finishing processes are taken into account at the drawing-board stage, the experience and advice of those who will be concerned with finishing can be much more usefully employed than when the article has actually been made.

'When the manufacturer undertakes the finishing of his own products—with existing plant that often represents a major capital investment—articles must be finished with the equipment and methods available. It is in this situation that prior discussion between the designer, the production engineer and the finishing departments can be most fruitful. When manufacturing and finishing are done by separate organisations, difficulties can be prevented by early consultation with the metal finisher or with others having specialised experience in metal finishing.

'Co-operation of this kind, and observance of the simple rules in this booklet, will help greatly in producing attractive and serviceable articles at minimum cost without sacrificing the designer's main intentions.'

* *We shall be pleased to supply a free copy of this booklet.*

Nickel Plating of Steel and Aluminium- and Copper-base Alloys: Specification

MINISTRY OF AVIATION: 'Process Specification: Electroplating of Aluminium, Steel and Copper with Silver and Nickel.'

Specification D.T.D. 919*B* (superseding *D.T.D.* 919*A*), Mar. 1960; 4 pp.

This specification 'covers the requirements for electroplated silver or nickel on aluminium-rich materials, on steels of minimum specified tensile strength not exceeding 90 t.s.i. (141·5 kg./mm.^{2}: 201,600 p.s.i.), or of minimum specified hardness not exceeding 405 HB or 430 HV, and on copper-rich materials, as specified in *DEF* 5000 or other documents'. Threaded steel parts are specifically excluded from the scope of the specification. The aluminium-rich materials covered will normally be in the wrought condition and will contain not more than 2 per cent. manganese, 3 per cent. magnesium, 5 per cent. copper, and 1 per cent. silicon; the term 'steel' relates normally to deep-stamping mild steel; the copper-rich materials will normally be copper, brass, bronze and copper-nickel alloys.

Requirements are specified with respect to: pre-treatment procedures; finish plating; heat-treatment; adherence and thickness (relevant adherence, thickness and humidity tests are laid down); and type approval.

The deposit thicknesses stipulated for parts plated with nickel are reproduced on p. 238.

Incorporation of Sulphur in Nickel Deposited from a Thiourea-containing Plating Solution

G. T. ROGERS, M. J. WARE and R. V. FELLOWS: 'The Incorporation of Sulfur in Electrodeposited Nickel, Using Thiourea as a Brightener and Leveler.'

Jnl. Electrochemical Soc., 1960, vol. 107, Aug., pp. 677–82.

A prerequisite stage to any investigation of the mechanisms of brightening and levelling during electrodeposition of nickel is the determination of the extent to which an additive, or compounds derived from the additive, become incorporated in the nickel deposit under various plating conditions.

Basis Metal or Alloy	Minimum Total Thickness including Undercoats (if any)	Minimum Thickness of Final Nickel Coating
Aluminium	0·0015 in. (0·0375 mm.) local	0·0004 in. (0·01 mm.) local
Steel	0·0010 in. (0·025 mm.) local	0·0004 in. (0·01 mm.) local
Copper*	0·0003 in. (0·0075 mm.) local	0·0003 in. (0·0075 mm.) local, or for barrel-plated parts, average

* For threaded parts, the final dimensions after plating shall not exceed the specified maximum for the part.

It is also important to know the extent to which anions are incorporated in the coating. The amounts incorporated are too small to be determined conveniently by conventional methods of analysis, but radiotracer techniques have proved suitable for this purpose, and their high analytical sensitivity may be combined with autoradiography to reveal in detail the distribution of the additive throughout the deposit. (BEACOM and RILEY have investigated the incorporation of sulphur compounds from sodium allyl sulphonate, using a counting technique and autoradiography to measure the differences between incorporation on the peaks and valleys of grooved cathodes: see abstract in *Nickel Bulletin*, 1959, vol. 32, No. 6, p. 177.) Addition of thiourea results both in brightening and levelling: this paper describes an investigation of the incorporation of sulphur into nickel deposited from a solution containing thiourea labelled with sulphur-35.

Plating solutions were prepared by adding S^{35}-labelled thiourea, diluted with inactive carrier, to a standard Watts nickel-plating solution. The amount of sulphur incorporated in the nickel coating was established as a function of current density, thiourea concentration and the roughness of the cathode surface. To investigate incorporation of sulphur from sulphate, other experiments were conducted in which the Watts solution contained labelled sulphate but no thiourea.

The nickel coatings deposited in the presence of thiourea were found to contain sulphur, the amount of which increased (when the current density was determined by the external electrical circuit or by the geometry of the plating cell) with decrease in current density. Autoradiographs taken from oblique sections cut through the nickel deposit revealed the distribution of the sulphur within the deposit. When the nickel was deposited on a surface having a roughness comparable to that encountered under commercial plating conditions, the sulphur was found to be incorporated on the peaks of the surface, a finding in agreement with that of Beacom and Riley. Thiourea causes levelling (which requires the peaks to be regions of lower current density), and it is therefore concluded that, when the current-density distribution is determined by the behaviour of thiourea on the rough surface, the incorporation of sulphur is greater in regions of lower current density. Sulphur was probably incorporated in layers in those regions of the deposit exhibiting a laminar structure.

On the basis of the data obtained using plating solutions containing labelled-sulphate anions but no thiourea, it is concluded that the sulphur incorporated from sulphate is very much less than that introduced *via* thiourea.

Corrosion Behaviour of Copper/Nickel/Chromium Electrodeposited Coatings

H. M. HEILING: 'The Corrosion Behaviour of Decorative Copper/Nickel/Chromium Coatings on Steel: The Corrosion Behaviour, in the 'Corrodkote' and Kesternich Tests, of Decorative Copper/Nickel/Chromium Coatings on Steel, with Special Reference to Duplex Processes.'

Metall, 1960, vol. 14, June, pp. 549-61.

The investigation reported originated in the considerable interest aroused in Germany by the introduction of duplex-nickel plating processes and the development, in the U.S.A., of the 'Corrodkote' accelerated-corrosion test. In view of this interest, it seemed appropriate to compare the 'Corrodkote' with the Kesternich* test in terms of the results obtained on various types of composite coating, including those incorporating duplex nickel.

Five types of undercoating (all deposited on a steel substrate) were selected for testing:

(1) A bright-nickel deposit.
(2) A duplex-nickel coating (comprising 26·6μ of sulphur-free nickel + 13·3μ of sulphur-containing bright nickel).
(3) A coating comprising 26·6μ of buffed dull nickel + 13·3μ of bright nickel.
(4) A 40-μ-thick coating comprising 20μ of buffed copper + 20μ of bright nickel.
(5) A 40-μ-thick coating comprising 20μ of buffed copper + 20μ of duplex nickel.

Coatings of these five types were evaluated as a function of three different chromium overcoatings:

(1) A 2·5-μ-thick duplex-chromium coating;
(2) A 1·3 or 2·08μ crack-free chromium coating;
(3) A 0·3-0·4μ conventional chromium overcoating.

The various coatings were exposed to the 'Corrodkote' and Kesternich tests. Potential measurements were also carried out, and specimens were subjected

* An accelerated-corrosion test, employed in Germany, which involves exposing the plated specimen to a water-vapour/SO_2/CO_2 atmosphere.

to metallographic examination after testing. Full particulars are given of the plating and test conditions employed in the study.

The data derived from the tests, presented *in extenso*, are discussed in relation to the findings of previous investigators in the same field.

The author's conclusions are similar to those reached by SAMPLE in his review of information available on the protective capacity of nickel/chromium electrodeposits (see abstract in *Nickel Bulletin*, 1960, vol. 33, No. 6, pp. 135–6.):

(1) Bright-nickel coatings confer less protection than buffed dull-nickel coatings of similar thickness when both coatings are plated with the usual thin bright-chromium overcoating from a conventional sulphuric-acid plating solution.

(2) The protection conferred by duplex-nickel coatings is similar to that of buffed dull-nickel coatings when the final overcoating is of conventional bright chromium.

(3) Thicker chromium coatings increase the corrosion protection conferred by bright-nickel coatings. (Further confirmation of this conclusion is, however, considered necessary.)

(4) Copper / bright-nickel / conventional-chromium coatings confer protection superior to similar coatings without copper when the exposure period is of short duration. The corrosion-resistance of such coatings is, however, inferior to that of duplex-nickel coatings or buffed dull-nickel coatings of the same thickness and with conventional chromium overcoatings.

These findings are supplemented in the present work by the following two conclusions:

(5) Copper/bright-nickel and copper/duplex-nickel coatings plated with crack-free chromium satisfactorily withstand the conditions of the Kesternich test.

(6) Copper / duplex-nickel / crack-free-chromium coatings confer satisfactory corrosion protection (as assessed by the 'Corrodkote' and Kesternich tests).

The metallographic results indicate that, irrespective of the type of chromium overcoating, the process of corrosion was practically the same in both tests, and the author comments that the quality of the chromium overcoating and the presence of pores and cracks must, it would seem, be regarded as the decisive factors governing the onset of corrosion.

Electrodeposition of Iron-Chromium-Nickel Alloys Approximating to the Composition of 18-8 Stainless Steels

W. MACHU and M. F. M. EL-GHANDOUR: 'Electrodeposition of Iron-Chromium-Nickel Alloys.'

Werkstoffe u. Korrosion, 1960, vol. 11, Aug., pp. 481–7.

The investigation described by the authors was undertaken to determine whether electrodeposition of an iron-chromium-nickel alloy approximating to the composition of an 18-8 chromium-nickel steel were feasible, and, if so, to develop a suitable plating solution and to establish optimum plating conditions.

It was found that such an alloy can be electrodeposited from an electrolyte containing urea* and the sulphates of iron, chromium and nickel, a result which is attributed to the fact that, at an appropriate solution composition and under suitable operating conditions, the deposition potentials of the three metals and that of the alloy virtually coincide at a value of $E_H = -0{\cdot}68$ v.

The data presented show that the deposition conditions for the alloy and the three metals are considerably influenced by the properties of a chromium-hydroxide film which formed on the surface of the cathode. The effect of this film on each metal was, however, not the same: when the experimental conditions were such as to increase the stability of the film and reduce its solubility, the amount of chromium deposited increased, and the amount of nickel deposited decreased; in the case of iron, the influence of the film was relatively insignificant. The film (even in the case of chromium) appeared to prevent the attainment of higher current efficiencies during plating.

When they were present simultaneously in the electrolyte, all three metals considerably obstructed each other during deposition. Their individual current efficiencies were much less than those obtained when they are separately electrodeposited (the smallest percentage decrease was exhibited by chromium). The current efficiency for the iron-chromium-nickel alloy did not, in general, exceed 25 per cent.

It is concluded therefore, that during deposition of the ternary alloy the metals polarize, rather than depolarize, each other. Depolarization is known to occur during deposition of alloys of iron and nickel with, for example, molybdenum and tungsten, the iron and nickel enabling the molybdenum or tungsten to be deposited in metallic form at higher current efficiencies from aqueous solutions: the behaviour of iron and nickel during electrodeposition of alloys varies therefore according to their partner. The effect of the chromium-hydroxide film on the cathode is deemed, in the present case, sufficiently great to outweigh considerably that of any depolarizing factors.

A solution of the following composition, operated under the conditions noted, is regarded as optimum for deposition of an alloy similar in composition to that of an 18-8 chromium-nickel steel:

	g./L.	*mol./L.*
$Cr_2(SO_4)_3.15H_2O$ (the violet form) ..	264·88	0·4
$FeSO_4.7H_2O$ ..	55·6	0·2
$NiSO_4.7H_2O$ ..	112·3	0·4
H_3BO_3	24·73	0·4
Urea	180·2	3·0
Density	1·285	
pH	2·1	
Temperature ..	40–45°C.	
Current density ..	12–20 amp./dm.^{2}	

See also following abstract

* The authors' investigation of the influence of urea on the electrodeposition of nickel was reported in *Werkstoffe u. Korrosion*, 1960, vol. 11, May, pp. 283-6: see abstract in *Nickel Bulletin*, 1960, vol. 33, No. 8-9, p. 191.

Influence of Plating Conditions on the Deposition of Iron-Chromium-Nickel Alloys

W. MACHU and M. F. M. EL-GHANDOUR: 'The Influence of Operational Conditions on the Composition of Iron-Chromium-Nickel Alloys Deposited from a Complex Urea-containing Metal-Sulphate Solution.'

Werkstoffe u. Korrosion, 1960, vol. 11, July, pp. 420–5.

The investigations described in the paper referred to in the preceding abstract had shewn that the plating solution noted could be used to electrodeposit a nickel-chromium-iron alloy approximating to the composition of an 18–8-type chromium-nickel steel. For practical application of this optimum solution it was, however, considered essential to determine the influence of the following plating variables on such factors as current efficiency and the composition, structure, appearance and brightness of the deposit: temperature, current density, plating time, cathode material (copper, brass, nickel, zinc, aluminium and iron). The experiments now reported were carried out to obtain the desired information.

Optimum plating conditions were found to be: pH 2·1–2·4; current density 10–15 amp./dm.^{2}; temperature 40°–45°C. Even with the optimum solution and operational conditions determined, however, the maximum current efficiency obtainable for the alloy was only about 25 per cent. The smallness of the value is attributed to the inhibitive effect of the chromium-hydroxide film formed on the surface of the cathode (see preceding abstract). Use of lower pH values and higher temperatures resulted in deposition of alloys of lower chromium and higher nickel contents; a pH of 2·1–2·4, a higher current density and a low solution temperature were conducive to the production of alloys of higher chromium content.

Deposition of an alloy approximating to the composition of an 18–8 steel necessitated a compromise between the optimum conditions established for current density and temperature. The relationships involved in deposition of the chromium and nickel are of particular significance in this connexion. Due to oxide and crack formation, maintenance of the current density at the high values (higher than 30 amp./dm.^{2}) corresponding to optimum current efficiency has a deleterious effect on the appearance of the deposits, and burnt areas occur. Use of a high temperature and low current density (in the range 10–15 amp./dm.^{2}) were found conducive to the formation of uniform crack-free deposits.

Production of Pattern Equipment by Means of the Nickel-Carbonyl Process

J. O. TRIMBLE: 'Nickel-Carbonyl Pattern Equipment.'

Modern Castings, 1960, vol. 38, Aug., pp. 65–8.

This article describes the procedure developed by the Carbonyl Metal Products Section of The Budd Company for the production of pattern equipment by gas plating a suitable master model with nickel (i.e., by deposition of nickel *viâ* thermal decomposition of nickel carbonyl).

The first step in the process, the creation of the master male model, is accomplished by standard pattern-making practice, using a convenient material such as wood, plastic or metal. After the pattern has been checked for accuracy, it is sprayed with release agent, and a female mould is then made from this master by spraying it with a eutectic metallic compound. The female eutectic mould is then placed in the deposition chamber, the chamber is closed and purged of all air with carbon dioxide, and the mould is heated to 325°F. (163°C.). At this point nickel carbonyl is introduced into the chamber from the gas-generating room, and, in contact with the hot mould surface, decomposes, depositing pure nickel on the surface of the mould and releasing carbon monoxide. The process is continued until the surface of the mould has been coated with the desired thickness of nickel, after which the reaction is stopped, the chamber is purged with carbon dioxide, and the nickel-plated eutectic moulds are removed. The nickel shell is stripped from the eutectic mould and is backed with epoxy resin. A metal base plate is cast into the epoxy to facilitate mounting, and the nickel surface is vapour blasted to remove all release agents. The result is an exact reproduction of the original model.

Patterns produced by means of the process consist of nickel exhibiting the following characteristics:

	p.s.i.	t.s.i.	kg./mm.^{2}
Tensile strength	85,000–95,000	38–42·5	60–67
Yield strength (0·2% offset)	46,000–56,000	20·5–25	32·5–40
Elongation, %		15–22	
Hardness, B.H.N.		181–222	

The nickel is tough, highly abrasion-resistant (exhibiting resistance to sand five times greater than cast iron), and has excellent release properties from sand binders.

The technique described is stated to decrease considerably the time-lapse between design and production stages, and the cost of such patterns is usually somewhat less than that of conventional machined patterns (as the pieces become more complex, the economic advantage of the nickel-carbonyl process becomes much greater). Due to the extremely high abrasion-resistance of the nickel, pattern life is lengthened and maintenance is reduced. Nickel-carbonyl patterns can, it is stated, be arc-welded, gas-welded, brazed, silver soldered or lead-tin soldered, and the process has already found application in the production of green-sand patterns, green-sand coreboxes, shell-mould patterns, shell core boxes, permanent moulds for aluminium foundries and die-cast inserts.

NON-FERROUS ALLOYS

Elastic Constants of Copper-Nickel Alloys

R. E. SCHMUNK and C. S. SMITH: 'Elastic Constants of Copper-Nickel Alloys.'

Acta Metallurgica, 1960, vol. 8, June, pp. 396–401.

The elastic constants of single crystals of copper and of dilute alloys of copper with nickel (nickel 2·34–9·73 per cent.) were measured by means of the ultrasonic pulse-echo technique.

In contrast to results previously obtained for solutes to the right of copper in the periodic table, the data presented show that all fundamental elastic constants increase with alloying content. In terms of $C_o^{-1}(dC/dx)$ the values determined are: C_{44}, (0·57); $(C_{11}-C_{12})/2$, (0·70); $(C_{11}+2C_{12})/3$, (0·17) per atom fraction. The authors have corrected the values for lattice parameter change upon alloying by using experimental data on the pressure derivatives of the elastic constants of pure copper: the remaining effect is due to alloying alone and is still positive for both shear constants. This result is interpreted as indicating a stiffening of the short-range crystal forces (because the neutral nickel ion-core is larger than the iso-electronic copper ion-core) and a decrease in the long-range electrostatic forces (because of the decrease in the average ion-core charge).

Thermodynamics of Formation of Nickel-Magnesium Compounds

J. F. SMITH and J. L. CHRISTIAN: 'Thermodynamics of Formation of Copper-Magnesium and Nickel-Magnesium Compounds from Vapour-Pressure Measurements.'

Acta Metallurgica, 1960, vol. 8, Apr., pp. 249–55.

A review of standard compilations having revealed no thermodynamic data relating to the formation of any of the compounds Mg_2Cu, $MgCu_2$, Mg_2Ni and $MgNi_2$, and accumulation of such data for a large number of intermetallic compounds being desirable in order to correlate energies and entropies of formation with crystal structure, and, hence, with intermetallic bonding, the authors undertook the investigation described to measure the vapour pressure of magnesium over a series of copper-magnesium and nickel-magnesium alloys.

Magnesium-vapour pressures were determined, using the Knudsen effusion method, at temperatures in the range 400°–1100°K. The free energies, enthalpies and entropies of formation of the four compounds computed from the vapour-pressure data are discussed by the authors. The results indicate that the bond strengths in the nickel-magnesium compounds are appreciably greater than in the corresponding copper-magnesium compounds.

Solubility of Hydrogen and Nitrogen in Liquid Nickel-Cobalt Alloys

See abstract in right-hand column.

Nickel Plating of Aluminium- and Copper-base Alloys: Specification

See abstract on p. 237.

NICKEL-IRON ALLOYS

Solubility of Hydrogen and Nitrogen in Liquid Iron-Nickel, Iron-Cobalt and Nickel-Cobalt Alloys

T. BUSCH and R. A. DODD: 'The Solubility of Hydrogen and Nitrogen in Liquid Alloys of Iron, Nickel and Cobalt.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, June, pp. 488–90.

Using Sievert's method of solubility measurement, a study was made of the solubility (at 1600°C. and 1 atm. gas pressure) of hydrogen and nitrogen in iron, nickel, cobalt, iron-nickel alloys, iron-cobalt alloys, and nickel-cobalt alloys.

The solubilities of hydrogen and nitrogen in nickel and iron were found to be as follows (the data agree well with the results obtained by earlier investigators):

	Wt. % H	Wt. % N	cc. H_2 per 100 g.	cc. N_2 per 100 g.
Iron	$2·68\times10^{-3}$	$39·5\times10^{-3}$	29·8	31·6
Nickel	$3·82\times10^{-3}$	0	42·5	0

Nitrogen is insoluble in pure nickel and cobalt, and, as might be expected, in nickel-cobalt alloys. Data on the solubility of nitrogen in iron-nickel alloys confirmed the findings of earlier work: the saturation value decreased with increase in nickel content in an approximately parabolic manner, and alloys containing more than 80 per cent. nickel dissolved very little nitrogen. The investigation demonstrated that the solubility of hydrogen in iron-nickel alloys increases non-linearly with increase in nickel content, and, at nickel contents exceeding 90 at. per cent., solubility was virtually independent of composition. The solubility of hydrogen in nickel-cobalt and iron-cobalt alloys, however, reached a minimum at 75 and 50 at. per cent., respectively. The solubility of nitrogen in iron-cobalt alloys decreased approximately linearly with increase in cobalt content. The interaction parameters determined by the authors are consistent with the observations of OHTANI and GOKCEN concerning a periodic relationship between the parameter and the atomic number of the alloying element.

Resistance Welding of Nickel-Iron Electronic-Component Leads to Nickel-clad Copper Wire

See abstract on p. 236.

CAST IRON

Influence of Alloying Elements on the Properties of Cast Iron

R. BARTON: 'The Influence of Alloying Elements in Cast Iron.'

B.C.I.R.A. Jnl., 1960, vol. 8, July, pp. 567–85.

The mechanical-property requirements stipulated for cast iron by *B.S.* 1452 : 1956 are generally met by suitable modification of the carbon, silicon, manganese, sulphur and phosphorus contents of the iron: higher strengths, or improvements in such properties as wear-, heat- or corrosion-resistance, are achieved by addition of alloying elements. In this review, in which reference is made to a *bibliography* of 20 items, the author considers the effects of such alloying additions on the properties and structure of cast iron.

The first section of the paper is concerned with the general effects of alloying additions (as reflected in changes in the solidification sequence, critical-transformation temperatures and transformation rate). In subsequent sections, dealing with the influence of individual addition elements (nickel, copper, chromium, molybdenum and vanadium), particular emphasis is placed on the modifications induced in the constitution, structure and mechanical properties of the iron, and on the principal purpose for which each alloying element is used. The paper contains numerous data supplementing or illustrating the author's textual comments.

In an appendix the costs, and methods, of adding alloying elements to cast iron are noted.

CONSTRUCTIONAL STEELS

Decomposition of Austenite in Low-Alloy Nickel-Chromium-Molybdenum Steel During Cooling

E. P. KLIER and T. H. YEH: 'The Decomposition of Austenite in 4340 Steel During Cooling.'

Amer. Soc. Metals, 1960, *Preprint* 183; 19 pp.

In an earlier investigation, it was found that the hardenability of A.I.S.I. 4340 nickel-chromium-molybdenum low-alloy steel could be increased by subjecting it to an initial slow cooling cycle through the critical range before quenching. In the studies now described further consideration was given to this finding.

Specimens of the same type of steel were subjected to end-quench hardenability tests, using standard and large-size test pieces, and a series of rounds were quenched to determine the effects of quenching in oil (*vis-à-vis* water). The hardenability data so derived were compared with cooling-transformation diagrams (determined from dilatation changes) and with isothermal-transformation diagrams (established by dilatation and metallography). Hardness curves obtained using the cooling-transformation specimens were compared with those measured for the quenched rounds and end-quenched bars. The results obtained were found to be sensitive to thermal treatment, and stabilization of the austenite to certain subcritical transformations was observed. A limited investigation of this stabilization effect is reported.

The authors draw attention to the following findings:

'The hardenability of a steel is a complex quantity, and, contrary to commonly accepted belief, the depth of hardening does not always increase as the cooling rate increases; for certain austenitizing conditions it may actually be reduced as the cooling rate increases. For the 4340 steel investigated in this work, reduction in hardenability was found to result from ferrite precipitation during rapid cooling from the low austenitizing temperatures. As the cooling rate was reduced, the austenite was stabilized with reference to this ferrite reaction, and the austenite then transformed to bainite and martensite at reduced temperatures.

'The effect of stabilization was dependent on the austenitizing temperature, and became more pronounced as the austenitizing temperature was reduced. The low austenitizing temperatures here noted are in the range from 1500° to 1550°F. (815° to 840°C.), and thus are not to be considered as uncharacteristic of temperatures used in practice. Temperatures as low as 1475°F. (800°C.) have been employed in the heat-treating of 4340 steel. The effect, therefore, may regularly intrude, in normal heat-treating, to influence hardenability results. Of particular importance are the changes in hardenability that may result from changes in cooling, either due to changes in section geometry or cooling environment, or both. At the present time it is not possible to project satisfactorily what these changes might be.

'The hardenability data in part correlate with the cooling-transformation data. Both types of data may be altered by changes in the cooling cycles employed in their measurement. In a qualitative sense the data are in agreement, with the austenite-stabilization effect being measured both for the cooling-transformation diagram and for the hardenability bar.'

Influence of Composition on the Shape of Martensite-Transformation Curves

R. BROOK, A. R. ENTWISLE and E. F. IBRAHIM: 'The Effect of Chemical Composition on the Shape of Martensite-Transformation Curves.'

Jnl. Iron and Steel Inst., 1960, vol. 195, July, pp. 292–8.

The martensite-transformation curves of many steels, where the transformation is 'athermal', have a similar shape. The initial part of the plot of percentage martensite against temperature is curved,

and leads into a linear range (between about 5 and 60 per cent. martensite). Beyond the linear range, the increment of transformation decreases as the temperature is lowered, and approaches zero toward M_f. The increment of transformation per °C. in the linear range is termed the slope. The main object of the work described in this paper was to determine, on the basis of this definition, the effect of composition on the slope of the transformation curve.

Of the sixteen steels studied (carbon contents ranged from 0·1 to 1·12 per cent.), eight contained 4·79–19·76 per cent. of nickel, the remainder were alloyed with 4–15·5 per cent. chromium. The Greninger-Troiano 'quench-temper' technique was adopted as a means of investigating the course of transformation.

The conclusions drawn from the transformation curves and other data contained in the paper are quoted below:

'(1) The martensite-transformation curves of a range of iron-nickel-carbon and iron-chromium-carbon alloys are linear in the range 5–55 per cent. transformation.

'(2) Within the limits of composition studied, the slope of the transformation curve can be represented approximately as a linear function of M_s (slightly different functions for the nickel and chromium steels). There are some anomalies when the M_s is below about 60°C. (i.e., high alloy and carbon contents).

'(3) The slope of the transformation curve is proportional to the thermodynamic function

$$\frac{\partial \Delta F^{\alpha' \rightarrow \gamma}}{\partial T}$$

although nickel and chromium steels give different correlations. There are again some anomalies in steels with high alloy and carbon contents. The relationship between M_s and slope follows this correlation.

'(4) In the composition range studied, the effects of nickel and chromium on M_s are comparable with the effects in low-alloy steels. Carbon is found to be much less effective in the nickel steels, and somewhat less in the chromium steels than in low-alloy steels.'

Influence of Structure and Microporosity on the Mechanical Properties of High-Strength Cast Steel

S. Z. URAM, M. C. FLEMINGS and H. F. TAYLOR: 'High-Strength Cast Steel: Structure and Microporosity: Effect on Mechanical Properties.'

Modern Castings, 1960, vol. 38, July, pp. 61–74.

The work reported was conducted during the second year of what is planned as a progressive investigation of the effect of solidification variables on the mechanical properties of high-strength cast steel. The programme is fundamental in nature, but has the ultimate objective of developing the basic information necessary to produce, reliably and economically, steel castings exhibiting good ductility at strengths in the region of 300,000 p.s.i. (134 t.s.i.: 211 kg./mm.²). During the first year of the programme, a preliminary study was made of the influence of solidification variables on (1) microsegregation, (2) microshrinkage, and (3) inclusion count and distribution. An important conclusion was that microporosity adversely affects the ductility of high-strength cast steels (which would be regarded as sound when examined by ordinary techniques). Ductility is a factor of prime importance in such steels (ductility and strength are inversely related), and if exceptionally high ductility can be obtained in a given steel at a given strength level, then the strength of that steel can be readily increased (by modifying the heat-treatment or carbon content), while still retaining adequate ductility for engineering applications.

Work during the second year, described in the present paper, has involved extensive theoretical and experimental studies of (1) the effect of solidification variables on casting macrostructure, i.e., columnar or equiaxe grains, (2) the effect of solidification variables on microporosity, (3) techniques for measurement of microporosity in steel castings, and (4) the influence of structure and microporosity on mechanical properties, particularly ductility. A nickel - chromium - molybdenum low - alloy high - strength steel (A.I.S.I. 4340) was employed throughout the study.

A technique for preparing thin samples (approximately 0·005 in. (0·125 mm.) thick) for microradiographic examination was developed and is described. Also discussed are techniques used to radiograph thin samples of steel and determine the microporosity present: the microradiographic technique was found particularly valuable for measuring microporosity n steel castings.

A series of solid cylinder castings was poured to investigate the effect of solidification variables on structure. The presence of a chill at the bottom surface produced a columnar zone, and a region relatively free from microporosity. The ductility of this columnar region was superior to that characteristic of the equiaxe regions of the cylindrical castings. A steel rod placed in the riser of a solid cylindrical casting resulted in substantial grain refinement of the equiaxe zone: gravity settling of the crystals formed in the region near the chill rod appeared to be the major grain-refining mechanism, and no improvement in mechanical properties was detected as a result of the grain refinement.

A 'denucleating' effect was observed in a casting that was gated through a vibrating steel box.

A series of plate castings ($\frac{1}{2}$ in. (12·5 mm.) thick) was produced to study the effect, on microporosity and mechanical properties, of plate length and chilling. Ultimate tensile strengths as high as 260,000 p.s.i. (116 t.s.i.: 182·5 kg./mm.²), yield strengths as high as 220,000 p.s.i. (98 t.s.i.: 154·5 kg./mm.²) and reductions-in-area of up to 40 per cent. were obtained near a chill (where microporosity was

essentially zero). Microporosity was found to increase (1) if the plate was not chilled, and (2) as the distance from the plate end (chilled or unchilled) increased. Mechanical properties, particularly reduction-in-area and elongation, decreased with increase in microporosity.

The effects of solidification rate and section size were investigated in step wedge castings. This series of experiments showed that castings could be produced with excellent mechanical properties throughout a 2-in. (5-cm.) thick section, provided that steep thermal gradients were maintained. The use of exothermic materials on one surface and a copper chill on the opposite surface enabled columnar grains to be grown throughout the section.

In studies in which the microporosity existing in various locations of all the test castings examined was correlated with the ductility of material from these locations, it was found that when microporosity was less than 0·5 per cent., a reduction-in-area of up to 40 per cent. was attainable in high-purity A.I.S.I. 4340 steel heat-treated to a strength level of 250,000–300,000 p.s.i. (111·5–134 t.s.i.: 175·5–211 kg./mm.^{2}).

Influence of Hydrogen on the Mechanical Properties of Low-Alloy Forging Steels

R. M. GOLDHOFF, S. YUKAWA and J. G. McMULLIN: 'The Effects of Hydrogen on the Mechanical Properties of Low-Alloy Rotor Forging Steels.'

Jnl. Iron and Steel Inst., 1960, vol. 195, July, pp. 298–302.

In recent years, the adoption of vacuum-pouring techniques has effectively eliminated the problems associated with residual hydrogen. The experimental work described in this paper was, however, undertaken before vacuum-poured forgings became widely available. Information was sought on four points: (*a*) the relationship between embrittlement induced by hydrogen introduced by laboratory charging and that induced in large air-poured forgings by residual hydrogen; (*b*) the effect of hydrogen on notch properties; (*c*) the degree to which vacuum-poured steel is susceptible to embrittlement; and (*d*) the delayed-failure characteristics of the medium-strength steels (tensile strength 120,000 p.s.i.: 53·5 t.s.i.: 84·5 kg./mm.^{2}) under consideration.

Nine grades of low-allow forging steel were tested: one of nickel-chromium-molybdenum type; one of chromium-molybdenum-vanadium type; the remainder of nickel-molybdenum-vanadium type. Compositions and heat-treatments are listed.

The relationship between the tensile ductility and hydrogen content of air-poured steels artificially charged with hydrogen was compared with that exhibited by specimens of the same steel trepanned directly from large forgings. A similar comparison was made in the case of steels of similar composition and heat-treatment which had been prepared (1) by vacuum-pouring and (2) by the consumable-electrode process. The effect of hydrogen on the notch properties of air-poured steels was determined by tensile and slow-bend tests on specimens charged under controlled conditions. Finally the delayed-fracture phenomenon was studied by means of static stress-rupture tests at room temperature (an artificial charging method was used in this phase of the investigation also). The test bars used were of a size sufficient to retain substantial amounts of hydrogen for long periods.

The authors conclude that: (*a*) the loss of ductility due to hydrogen embrittlement is greater for the steel charged artificially than for the same steel containing residual hydrogen introduced *viâ* the steel-making process; (*b*) notch strength and ductility both decrease considerably as a result of the presence of hydrogen; (*c*) vacuum-poured steel is susceptible to hydrogen embrittlement, but less so than air-poured steel; (*d*) delayed-fracture phenomena occur in the steels studied.

Hardenability Effect of Boron on Steel

R. A. ORANGE and J. B. MITCHELL: 'On the Hardenability Effect of Boron in Steel.'

Amer. Soc. Metals, 1960, *Preprint* 188; 29 pp.

Work on the effects of boron in commercial steels has given rise to four findings: (*a*) little or no correlation has been established between the amount of boron present and the hardenability effect; (*b*) the hardenability effect of the element is diminished after austenitizing at relatively high temperature; (*c*) the hardenability effect varies markedly with the carbon content of the steel; and (*d*) a special constituent (designated 'B' in the present paper) is formed after certain heat-treatments. The boron constituent has hitherto been regarded simply as a manifestation of the presence of boron, but the present authors assumed that a systematic study of 'B' as a function of austenitizing treatment would contribute to an understanding of the behaviour of boron steels, and since the effect of boron is markedly dependent upon carbon content, it was decided to investigate the hardening characteristics of boron steels differing widely in carbon content: see compositions below.

C %	Mn %	Si %	Ni %	Cr %	Mo %	Al %	B %
0·23	0·72	0·20	0·59	0·52	0·21	0·07	None
0·22	0·76	0·20	0·57	0·51	0·20	0·08	0·0025
0·50	0·77	0·22	0·60	0·51	0·22	0·07	None
0·50	0·77	0·23	0·60	0·50	0·21	0·11	0·0016
0·79	0·77	0·23	0·58	0·50	0·21	0·05	None
0·78	0·81	0·26	0·59	0·49	0·21	0·12	0·0025

Full details are given of the conditions under which the experiments were carried out. The conclusions drawn from the extensive data presented in the paper are summarized as follows:

'The effect of boron on hardenability in a matched series of Type 8600 steels containing 0·2, 0·5 and

0·8 per cent. carbon was less the higher the carbon content. An important factor in the diminishing effect of boron with increasing carbon is the tendency for the amount and rate of precipitation of boron constituent ('B') to increase as carbon is higher. In each of the steels, the mutual relationship between austenitizing temperature, precipitation temperature, and precipitation time is summarized by a family of 'C'-shaped curves. In a particular steel, 'B' precipitates sooner and in greater quantity as the austenitizing temperature is increased, in accordance with increasing solubility of boron at higher austenitizing temperatures. Precipitation of 'B' prior to, or in the early stages of, transformation of austenite results in a decrease in the effectiveness of boron, both because of depletion of boron at austenite grain boundaries where the 'B' precipitates, and because, at the higher transformation temperature, precipitated 'B' particles have a nucleating effect.

'The loss in effectiveness of boron on austenitizing at higher and higher temperature is explained by an accompanying increase in rate of subsequent precipitation of 'B'. In a particular steel, the hardenability effect of boron increases, as more boron is dissolved, only up to the point where additional dissolved boron leads to too rapid precipitation of 'B'.

'When the hardenability effect of boron is diminished by austenitizing above the temperature which dissolves a larger percentage of boron than is optimum for that particular steel, partial recovery of the hardenability effect results if the steel is given a special heat-treatment to precipitate some of the excess boron as coarse particles before cooling austenite to its transformation temperature range. This sort of treatment possibly may be used to enhance the hardenability effect of boron in relatively high-carbon steels.

'Study of the effect of hot working, which recrystallizes prior coarse austenite grains, on the precipitation of 'B', and on the loss in hardenability with increasing austenitizing temperature, suggests that boron migrates to grain boundaries and possibly to other crystal imperfections during cooling. The assumption that, just prior to transformation, boron atoms are preferentially located at preferred nucleation sites, rather than randomly distributed in the bulk austenite, may explain why a minute percentage of boron has, compared with other alloying elements, an astonishingly large effect.'

Atmospheric-Stress-Corrosion Tests on Steels for Aeronautical Applications

See abstract on p. 256.

Development of a Non-Embrittling Cadmium-Plating Process for High-Strength Steels

S. W. STRAUSS and P. N. VLANNES: 'Progress toward the Development of a Non-embrittling Cadmium Electroplating Process. IV. Use of Methanol as a Solvent in Cadmium-Plating Solutions.'

Plating, 1960, vol. 47, Aug., pp. 926–31.

In an attempt to develop a cadmium-plating process which would not cause embrittlement when used to plate ultra-high-strength nickel-chromium-molybdenum steel (A.I.S.I. 4340), work has been carried out on (1) aqueous solutions fundamentally different from the cyanide bath, and (2) non-aqueous solutions. The paper reporting the investigations which culminated in the development of a non-embrittling aqueous solution was abstracted in *Nickel Bulletin*, 1960, vol. 33, No. 1–2, p. 13; the present paper records the results of work in which methanol was used as a solvent for the cadmium salt.

The plating characteristics of cadmium-methanol and cadmium–triethanolamine–methanol (TEAM) solutions, with and without additives, were investigated. Satisfactory deposits were obtained from the former solution at cadmium concentrations in the region of 0·9–1·35 M/1. In the case of the TEAM bath, the most satisfactory coatings were deposited from solutions containing (at a constant concentration of 275 ml. of methanol): (1) 0·69 mole TEA and 0·82–1·23 M/1 cadmium; (2) 1·26 moles TEA and 0·76–1·14 M/1 cadmium; (3) 1·74 moles TEA and 0·4–1·75 M/1 cadmium; (4) 2·16 moles TEA and 1·28–1·6 M/1 cadmium.

The results of delayed-fracture tests on cadmium-plated notched specimens of A.I.S.I. 4340 steel indicated that both the cadmium–methanol and TEAM solutions are non-embrittling.

Explosion-Bulge Tests on Armour Weldments

S. M. SILVERSTEIN, R. P. SOPHER and P. J. RIEPPEL: 'Explosion-Bulge Tests of Armor Weldments.'

Welding Jnl., 1960, vol. 39, July, pp. 309s–14s.

In the U.S.A., the H-plate test has, since the early part of World War II, been regarded as the standard test for evaluating the toughness of welded joints in ordnance armour, although many unsuccessful attempts have been made to find a less expensive substitute. The investigation described by the authors was undertaken to determine whether the explosion-bulge test* would be equally satisfactory for evaluating the ballistic properties of armour weldments.

Four series of bulge plates in 1-in. (2·5-cm.) Army Ordnance armour were welded with ferritic (Grades 260, 230 and 180) and austenitic (Type 307) electrodes: see composition on p. 246. These plates were then tested at temperatures ranging from +215° to −100°F. (+100° to −75°C.).

The ratings of the bulge-plate weldments, as assessed in this series of tests, were compared with the ratings allotted to four series of H-plate weldments (produced from the same basis metal using the same four grades of electrode) studied in a previous investigation.

In the explosion-bulge tests the weldments were evaluated on the basis of reduction in plate thickness

* In the explosion-bulge test, the specimens are placed on a circular die plate and are deformed into the die by means of an explosive shock. An area of uniform biaxial loading is produced in the centre of the pole area of the bulge, and, in bulging a weldment, the weld metal, heat-affected zone and adjacent basis metal are subjected to essentially uniform biaxial loading in the pole area.

Composition of Electrodes used in Explosion-Bulge Tests

(*See abstract on p. 245*)

Material	C %	Mn %	Si %	Ni %	Cr %	Mo %	V %
Armour Plate	0·25	1·58	0·16	—	—	0·45	0·01
Grade 260	0·07	0·75	0·33	1·75	—	0·80	0·20
Grade 180	0·10	0·70	0·35	—	—	—	—
Type 307	0·09	3·78	0·64	9·66	20·22	1·40	—
Grade 230	0·07	0·74	0·41	1·72	—	0·29	0·13

prior to failure, and of the amount of shear on the fracture face. Reduction in plate thickness was taken to be a measure of the resistance of the weldments to crack initiation. The amount of shear was regarded as a measure of the resistance of the weldments to fracture propagation.

The performance of the weldments made with high-strength ferritic electrodes did not differ greatly from that of those produced with the austenitic electrode; the weldments prepared with Grade 180 electrodes were, however, decidedly inferior to the other weldments. The ratings assigned on the basis of the explosion-bulge test were in general agreement with those assigned using the H-plate test as a criterion.

The results of the investigation are regarded as indicative that the explosion-bulge test is a useful method of determining the toughness performance of Army Ordnance armour weldments, provided that extreme care is taken in interpreting the test results. Further work in this connexion is recommended.

Suitability of High-Strength Steels for Welded Structures

R. D. STOUT: 'Higher-Strength Steels for Welded Structures.'

Welding Jnl., 1960, vol. 39, July, pp. 273s-83s.

In the chemical and oil industries, new process developments are governed, to a great extent, by the degree to which the material of construction withstands the application of increased pressures and wider ranges of temperature. Since these severer conditions can no longer be met on a practical or economical basis by carbon steels, an alternative approach is to design to higher stress levels in thinner sections, a solution to the problem which offers advantages in forming, welding and heat-treating the steel. The most difficult task in selecting a suitable steel for a given application is to determine the properties required in the steel: in addition to conventional tensile properties, other characteristics such as notch toughness, fatigue-resistance, or creep-resistance may require consideration. Since low-alloy steels meet these requirements better than carbon steels, the author has, in this paper, attempted 'to summarize the evidence which has been collected on the suitability of low-alloy steels for weldments designed to higher operating stresses'. The investigations on which the paper is based were sponsored by the Pressure Vessel Research Committee of the Welding Research Council.

The twelve steels studied (carbon steels, a 3·5 per cent. nickel steel, a molybdenum steel, and nickel-molybdenum, nickel-chromium-molybdenum, chromium-molybdenum-nickel steels, some containing small additions of vanadium, titanium, copper or boron) were selected to provide properties ranging from those exhibited by a low-carbon steel to those typical of a quenched-and-tempered steel exhibiting a tensile strength of over 120,000 p.s.i. (53·5 t.s.i.: 84·5 kg./mm.^{2}).

The paper is in two sections. In the first, the author summarizes the data obtained on the mechanical properties of the steels studied, and takes account of such factors as: the limitations that can be imposed on the cooling rates during heat-treatment; tensile properties; notch-ductility; fatigue-resistance; the influence of cold work and strain ageing; the effects of exposure to elevated temperatures. In the second section he is concerned with the results of studies of the welding characteristics of the steels.

Summarizing the points raised in his discussion of the data presented, the author comments: ' . . . the laboratory tests, for what they are worth, have furnished favorable evidence of the suitability of these steels for weldments designed to higher stresses.

'First, considerable gains in tensile strength can be obtained by the use of low-alloy compositions, particularly in heavier sections. Second, the increased strength is not obtained at the sacrifice of notch-ductility, but indeed with the possibility of concomitant increase in toughness. Third, fatigue-resistance increases roughly as the tensile strength, and does not appear to be a limiting factor in the use of the steels.

'An important advantage accompanying the application of higher-strength steels that is not always taken into consideration is the fact that reduced sections are possible because of higher-design stresses. The fact that thinner sections are involved in the fabrication compensates to a great extent for the forming and welding problems that may be encountered in alloy steels.

'Accelerated cooling can be used to raise the strength and notch ductility of these steels, but the response of the steel depends on its hardenability. The alloy content is more critical to the properties of the steel than the range of cooling rates that can be imposed on steels of relatively heavy sections. A good deal has yet to be learned about the applicability of accelerated cooling. Tests are presently in progress to determine whether improved surface properties will be effective in raising the service usefulness of sections above 1-in. (2·5-cm.) thickness.

'Among the remaining problems is the development of electrode materials and welding techniques which will produce weld metal that fully matches the potential properties of the base material. The higher the specification of design stresses, the more difficult this objective becomes.'

HEAT- AND CORROSION-RESISTING MATERIALS

Solid-Solution and Second-Phase Strengthening of Nickel-base Alloys

R. M. N. PELLOUX and N. J. GRANT: 'Solid-Solution and Second-Phase Strengthening of Nickel Alloys at High and Low Temperatures.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, Apr., pp. 232–7.

Work on the development of stable creep-resisting alloys, while comprehensive and systematic, has been highly empirical, and, whereas rules for strengthening alloys at low temperatures can be applied with some success to the more simple systems, their extension to behaviour at high temperatures is very poorly understood and has been complicated by important exceptions and deviations in terms of atom size or valency effects. The occurrence of both solid-solution weakening and second-phase weakening at high temperatures is of particular interest in this connexion, and, together with solid-solution and second-phase strengthening, formed the main subject of study in the experiments described. Ductility and the rôle of structure in the behaviour patterns were also investigated.

The chromium, molybdenum and tungsten contents of the nickel-chromium, nickel-molybdenum and nickel-tungsten alloys investigated covered a range ensuring production of both single-phase and duplex alloys. The sixteen alloys, which were vacuum-melted and -cast, were solution-treated to achieve a comparable grain-size. The duplex alloys were over-aged in an effort to produce a stable structure for testing at 1200° and 1500°F. (650° and 815°C.). Specimens were then subjected to tensile tests at room temperature and to stress-rupture tests (lasting for from 0·1 to 500 hours) at 1200° and 1500°F.

The authors' comments on the data presented (yield stress and stress for 1- and 100-hour rupture life are plotted as a function of the at. per cent. of soluble element) are quoted below.

'At temperatures where recovery and diffusion become important, that is, above about 0·45 T_m, solid-solution strengthening is dependent upon the slowing down of these mechanisms. At test temperatures of 1200° and 1500°F., corresponding to 0·53 and 0·63 T_m (referred to nickel), the diffusion mechanisms control the rate of recovery. It appears that significant solid-solution strengthening in these alloy systems occurs only for large amounts of solute element, above 10 at. per cent. and close to the solubility limit. Knowledge of the rate at which the coefficients of diffusion change with amount and type of solute element, or knowledge of the recrystallization temperatures of these alloys, would provide useful information regarding solid-solution strengthening at high temperatures.

'In two-phase binary alloys, it could be expected that those which contain compounds like Ni_4W or Ni_4Mo would be stronger than those which are mixtures of two terminal solid solutions. The stability of the second phase would determine the response of the structure to time and strain at temperature. In this regard, there can be no doubt about the superior stability of the Ni_4W and Ni_4Mo phases; yet even here there was observed weakening in supersaturated alloys under certain test conditions, similar to that observed in the nickel-chromium system. As yet this weakening is not explicable. The weakening in the nickel-chromium system may be associated in part with the weakness of the interface of the pearlitic colonies with the matrix, but this explanation does not apply in the case of the other two systems.

'At room temperature for all of the single-phase alloys, and at high temperatures for single-phase alloys with less than about 10 at. per cent. of solute, the expected effects of change in lattice parameter and valency seem to apply. At high temperatures, for solute contents greater than about 10 at. per cent. in these three systems, there are large deviations from known rules. Reasons for the superiority of nickel-molybdenum alloys over nickel-tungsten solid-solution alloys containing more than 10 at. per cent. of solute would be extremely valuable; however, explanations of this effect and other observations cannot be made until vastly more data are available better to define the patterns of behaviour among elements.'

Influence of Boron and Zirconium Additions on the Properties of a Nickel-base Heat-Resisting Alloy

R. F. DECKER and J. W. FREEMAN: 'The Mechanism of Beneficial Effects of Boron and Zirconium on Creep Properties of a Complex Heat-Resistant Alloy.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, Apr., pp. 277–85.

The information contained in the paper is closely cognate with that given in *National Advisory Committee for Aeronautics Tech. Note* 4286: see abstracts in *Nickel Bulletin*, 1959, vol. 32, No. 1, pp. 16–17; No. 12, p. 370.

Phase Transformations in Nickel-base Alloys

J. R. MIHALISIN and R. F. DECKER: 'Phase Transformations in Nickel-rich Nickel-Titanium-Aluminium Alloys.'

Trans. Metallurgical Soc., A.I.M.E., 1960, vol. 218, June, pp. 507–15.

Although control over the high-temperature properties of nickel-base heat-resisting alloys hardened with aluminium and titanium additions has been facilitated by application of the microstructural data provided by equilibrium diagrams, there are, in the case of alloys hardened predominantly with titanium, notable instances in which properties cannot be correlated with microstructure and equilibrium diagrams. It has been noted that a face-centered-cubic phase precipitates and transforms to η (close-packed-hexagonal Ni_3Ti) in stress-rupture tests, and that this face-centred-cubic phase is present in nickel-chromium-titanium alloys even when aluminium is excluded. Age hardening in iron-nickel-base alloys has been attributed to η, to γ' (face-centred-cubic phase based on Ni_3Al), and to both phases, but, on the basis of the nickel-titanium-aluminium equilibrium diagram, it has proved difficult to understand the presence of γ' in low-aluminium alloys. Furthermore, the characteristic coarse dispersion of η has not been commensurate with the marked ageing response. Recently a transition face-centred-cubic Ni_3Ti phase has been noted in titanium-hardened nickel-base alloys. Anomalous grain-boundary transformations which have markedly reduced notch stress-rupture properties in the iron-nickel-base alloys have been related to boron content and the effects of cold work. The authors' review of the relevant literature (to which due reference is made in the paper) led them to the conclusion that a transition phase was of significance in the nickel-titanium-aluminium system. The purpose of the study now described was to identify this phase, determine its transformation characteristics and kinetics, and attempt to correlate these findings with the age-hardening mechanisms. Time-temperature-transformation studies were, because of their adaptability to transition phases, considered of most value to, and were therefore used in, the present investigation.

The compositions studied (see below) were designed to attain equal ageing potentials of approximately 15 vol. per cent. of the equilibrium precipitate.

Ti at. %	Al at. %	B at. %
12·2	<0·02	<0·005 (<10 p.p.m.)
11·2	1·1	0·002
8·0	4·6	—
4·1	9·4	—
<0·01	14·5	<0·005
12·3	<0·02	0·025 (50 p.p.m.)

Hot-forged and rolled stock was sectioned into microspecimens which were solution-treated in argon for 2 hours at 2200°F. (1205°C.) and then water quenched. The specimens were subsequently aged isothermally in the range 1100°–1600°F. (595°–870°C.) for times up to 1000 hours. To study the effect of residual cold work, the nickel–12·2 titanium heat was (after solution-treatment and prior to ageing) cold-reduced 20 per cent. by rolling. The heat-treated specimens were examined by X-ray diffraction and by light and electron microscropy, and the microstructural findings were correlated with data derived from hardness measurements at room temperature and temperatures in the range 1000°–1400°F. (540°–760°C.).

The extensive test data outlined in the paper are supplemented by electron and optical micrographs. Consideration of these results leads the authors to conclusions which they summarize as follows:

'(1) Under non-equilibrium conditions during precipitation from the parent γ solution, all the aluminium atoms in the Ni_3Al (γ') structure can be replaced by titanium, to give a continuous series of solid solutions terminating in f.c.c. Ni_3Ti in nickel-rich alloys of the nickel-titanium-aluminium system.

'(2) This non-equilibrium titanium-rich γ' phase decomposes to the equilibrium η phase by a grain-boundary reaction and an intragranular reaction.

'(3) Replacing titanium by aluminium retards both the cellular and intragranular conversion of non-equilibrium γ' to η. The magnitude of the retardation increases with the degree of substitution.

'(4) Boron additions retard the grain-boundary precipitation of η, but have little effect on the intragranular conversion to η.

'(5) Residual cold work accelerates the decomposition of non-equilibrium γ' to η, both at grain boundaries and intragranularly.

'(6) Age hardening, even in nickel-titanium binary alloys, is from coherent γ'. Transformation of γ' to η results in overaging.

'(7) The magnitude of age hardening of nickel-titanium-aluminium alloys is a function of the disregistry between the lattices of γ and γ' and the resultant coherency strains. The maximum ageing response and disregistry is at approximately a 1·7 to 1 atomic ratio of titanium to aluminium.'

Microstructural Changes in Nickel/Titanium-Carbide Cermets

H. W. NEWKIRK, H. H. SISLER and T. S. SHEVLIN: 'Microstructural Changes in Titanium-Carbide-Base Cermets at 2000°F.'

Amer. Ceramic Soc. Bull., 1960, vol. 39, July, pp. 370–1, 374–6.

It is known that at 2000°F. (1095°C.) the strength of nickel/titanium-carbide cermets decreases more rapidly with time than would be expected on the basis

of the mechanical properties of the individual constituents and their mechanical constraint in the cermets. Consideration of data on the solubility of titanium, niobium and tantalum carbide in nickel at 2000°F., and of findings indicating an interrelationship between the strength and microstructure of single-phase and multiphase solids, prompted the authors to the hypothesis that if a solid-state solution/precipitation process occurs in the cermets at 2000°F., it will be accompanied by microstructural changes which would contribute to an understanding of the anomolous strength behaviour. The investigation reported in this paper was conducted in an attempt to verify or refute this hypothesis.

The material transport process was studied by heating specimens of Kentanium 'K-151-A' and 'K-152-B' in helium at 2000°F. for times up to 1000 hours. After exposure the specimens were quenched in oil (to retain phases or conditions stable at high temperatures), and examined by optical and quantitative microscopy and X-ray diffraction techniques.

The test procedure and equipment employed in the study are fully described. The nominal composition and density of the materials investigated are noted in the table below.

The results of the study are considered to validate the authors' original hypothesis. Microstructural changes were found to have occurred in the samples heat-treated for 1000 hours (although no change in crystal structure was determined). Statistical tests at the 5 per cent. level demonstrated that, in the case of the nickel phase of the 'K-152-B' cermet, significant changes had occurred in the average cross-sectional area, average linear intercept, interfacial-area/volume ratio, and the interfacial area per unit volume of the cermet. In the case of the nickel phase in 'K-151-A', however, significant changes in the same four properties could be established only at the 10 per cent. level. The magnitude of the changes in the nickel phase of 'K-152-B' are estimated as follows: the average cross-sectional area increases 22 per cent.; the average linear intercept increases 23 per cent.; the interfacial area to volume ratio decreases 20 per cent.; and the interfacial area per unit volume of the cermet decreases 10 per cent. The following are given as the best estimates of the magnitude of the changes in the nickel phase of 'K-151-A': the average cross-sectional area increases 11 per cent.; the average linear intercept increases 13 per cent.; and the interfacial area to volume ratio decreases 13 per cent.

These observations are in agreement with the modifications in microstructure anticipated from a solid-state solution/precipitation process, the proposed features of which are: 'Solution of carbide occurs in the nickel phase at points, corners, edges or other areas of high surface free energy, to give a solid solution which is supersaturated with respect to surfaces with lower free energy. Equilibrium saturation conditions are maintained in the nickel phase by precipitation of carbide at crevasses, sharp re-entrants or other areas of lower surface free energy. Carbide is transported through the nickel phase by volume diffusion. The driving force is derived from the consequent reduction in total interfacial free energy. Upon cooling, carbide in excess of the solubility limit precipitates out of solid solution.'

The findings of the study are considered to suggest that, if the solution/precipitation process occurs under stress, strong nickel/carbide interfacial bonds will be replaced by weaker carbide/carbide bonds, and the strength of the cermets at 2000°F. will decrease. It is concluded that a decrease in the solid solubility of the carbide phase in the nickel phase at 2000°F. should increase the strength of such cermets.

Influence of Heat-Treatment and Composition on the Microstructure and Creep Behaviour of 'Nimonic 80A'

C. W. WEAVER: 'Influence of Heat-Treatment and Composition on the Microstructure and Creep Behaviour of a Nimonic 80A-Type Alloy.'

Jnl. Inst. Metals, 1960, vol. 88, July, pp. 462-7.

Studies of many commercial nickel-base heat-resisting alloys have shown their microstructure and properties to be influenced by heat-treatment. Work on the 'Nimonic' alloys has demonstrated that ductility is governed by heat-treatments causing carbide precipitation at grain boundaries (and, possibly, local chromium impoverishment). The author's own investigations of laboratory-produced alloys of 'Nimonic 80A'-type have served to extend and somewhat modify these findings, in that the optimum intergranular structure was found to be duplex, containing both carbides and γ' phase,

Nominal Composition and Density of Cermets

(*See abstract on p. 248*)

Specimen	Ni		Solid-Solution Phase (TiC, TaC, NbC)		TiC	Apparent Density
	wt. %	vol. %	wt. %	vol. %	wt. %	(g./cc.)
'K-151-A'	20	12·9	15	87·1	65	5·7
'K-152-B'	30	19·7	8	80·3	62	5·81

$Ni_3(Ti,Al)$. This structure was produced by solution-treatment at 1200°C., followed by direct transfer to a fairly high ageing temperature. The structures were dependent both on heat-treatment and on alloy content, particularly with respect to carbon, and, to a lesser extent, with respect to titanium and aluminium which form γ' phase. Boron and zirconium also segregated with carbide at grain boundaries, but the beneficial effects of the carbide structure on creep were independent of their presence. Microstructure was found to affect creep behaviour through its influence on the rate of nucleation and growth of intergranular cracks and cavities (*ibid.*, 1960, vol. 88, Mar., pp. 296–300: abstract in *Nickel Bulletin*, 1960, vol. 33, No. 5, p. 114).

In the investigation described in the present paper, a study was made of the influence of heat-treatment on the microstructure of heats of alloy falling within the following composition range: chromium 19·6–21·0, titanium 2·18–2·83, aluminium 0·96–1·64, carbon 0·015–0·08, iron ~0·3, silicon ~0·35, manganese ~0·25, sulphur ~0·003, per cent., remainder nickel. Some of the specimens contained approximately 0·04 per cent. zirconium or 0·006 per cent. boron.

The effects of microstructure on creep behaviour are outlined by the author in relation to specimens subjected to one of two heat-treatments: the first involved rapid cooling from solution-treatment, which resulted in fine dispersion of carbide during ageing; the second involved direct transfer from solution-treatment to the ageing treatment and resulted in coarse segregation of carbide to the grain boundaries.

It was found that the microstructure resulting from certain heat-treatments (i.e., those that affected distribution of carbide and γ' phases) had an important influence on creep behaviour, and governed both time-to-rupture and elongation.

Creep behaviour was controlled mainly by the rate of cooling and the temperature of ageing after solution of carbides at 1200°C. Rapid cooling to room temperature, followed by re-heating to a precipitating temperature, produced finely dispersed carbides in the matrix, resulting in brittle fracture and short times to rupture.

Coarse precipitation of a duplex-carbide/γ' phase completely filling the grain boundaries (resulting from direct-transfer heat-treatments) gave rise to extended life, with high elongations at fracture.

The results indicate that the optimum temperature for precipitation is 950°–980°C. The carbon content of the alloy should lie between 0·03 and 0·08 per cent., and the solubility limits of γ' phase should be in the region of 950°C. (i.e., titanium 2·5, aluminium 1·5, per cent.) for maximum response to this heat-treatment.

For heats not containing zirconium or boron, direct ageing at 950°C. converted poor material into satisfactory material, an effect which is considered to suggest that the intergranular-carbide structure delays the fracture process by a mechanism complementary to that of the trace additions.

Thermal-Fatigue Behaviour of Nickel-base High-Temperature Alloys

E. GLENNY and T. A. TAYLOR: 'A Study of the Thermal-Fatigue Behaviour of Metals.'

Jnl. Inst. Metals, 1960, vol. 88, July, pp. 449–61.

Components of aircraft gas turbines, especially the turbine blading, are frequently exposed to conditions conducive to thermal fatigue (e.g., during start-up and changes of load). The trend in engine development is towards increased operating temperatures (making the temperature gradients still more severe), and thermal fatigue is therefore a likely cause of turbine-blading failure. This situation led to the development of a new laboratory technique for studying thermal-fatigue behaviour, involving the use of hot and cold fluidized beds as the heating and cooling media (*ibid.*, 1959, vol. 87, May, pp. 294–302 : abstract in *Nickel Bulletin*, 1959, vol. 32, No. 7, p. 230). The purpose of the investigation now described was to determine the effects, on the thermal-fatigue properties of high-temperature alloys, of varying the test conditions and the shape and size of the specimen.

In varying the test conditions, a study was made of the influence of the following factors: the nature of the thermal cycle (rapid heating, or rapid cooling, or alternate rapid heating and cooling); the time of immersion at T_2 (the upper cycle temperature); the upper and lower cycle temperatures T_2 and T_1; the test environment (comparative tests were conducted in air and in purified argon); the heat-transfer coefficient.

As 'Nimonic 90' is currently used in the rotor blading of many aircraft gas turbines, the major part of the experimental work was carried out on this alloy. The significance of such factors as the nature and upper temperature of the cycle may, however, vary with composition, and several other heat-resisting alloys were therefore also investigated in the test programme (i.e., 'Nimonic 80A', 'Nimonic 95', 'Nimonic 100', 'Nimonic 105' and 'G.64'), and, for comparative purposes, it was decided to include in the study two heat-resisting alloys of relatively low creep-resistance (i.e., 'Nimonic 75' and 'Nimonic DS'). The effects of specimen design were determined by tests on tapered discs of varying size and shape, on circular cylinders and on simple uncambered aerofoils of constant section. Specimens were subjected to metallographic examination after testing.

Full details are given of the test procedures and conditions employed. The data derived from the investigation lead the authors to conclusions which they summarize as follows:

'(1) A succession of heating shocks is generally more damaging than a succession of cooling shocks between the same temperature limits. The explanation is believed to be that rapid heating produces a transient compressive strain at the surface, and this is of sufficient intensity to cause plastic deformation. In consequence, when the specimen reaches a uniform temperature, a residual tensile strain

remains in the surface layers, which acts at the maximum temperature, when the material is at its weakest. In a cooling shock, the maximum transient tensile strain is developed in the surface at a much lower temperature.

'(2) The residual tensile strain referred to above is developed to its fullest extent only if sufficient time is allowed for the specimen to reach thermal equilibrium. If the heating time is insufficient, the severity of the heating shock is reduced and the thermal endurance may be greatly increased.

'(3) The upper temperature of the cycle is a dominating factor. For constant thermal strains, increase in the upper temperature generally reduces endurance values by reason of the diminishing strength of the material. At the highest temperatures, i.e., above 920°C., some other factor, perhaps the increased ductility of the material, appears to counterbalance its reduced strength in such a way that thermal endurance ceases to diminish with increasing temperature.

'(4) Thermal-fatigue cracks originate at the surface and, with few exceptions, are intercrystalline in origin and mode of propagation, thus showing the characteristics of creep rather than vibration-fatigue failure.

'(5) Surface oxidation, which is intergranular in nature for nickel-base alloys, has a significant effect on thermal-fatigue life. The use of an inert atmosphere gives an appreciably longer endurance than an air atmosphere.

'(6) The effects of shape and size are generally in line with predictions based on physical theory, i.e., increase in size (for similar shapes) and decrease in edge radius (for similar sizes) reduced endurance.

'(7) Increase of thermal strains resulting from greater temperature difference (ΔT), or greater rate of heat transfer, naturally tends to reduce endurance. Increase in the ΔT value progressively reduces endurance, but the effect of the heat-transfer coefficient varies with the nature of the cycle and the testing technique.

'(8) The results obtained in the laboratory with the fluidized-bed technique are generally confirmed by cascade-tunnel test results.'

Recommended Practice for Machining 'Nimonic' Alloys

'Machining 'Nimonic': Recommended Practice in the Processing of the Wiggin High-Nickel Alloys.'*
Aircraft Production, 1960, vol. 22, June, pp. 236–9; July, pp. 275–9.

The 'Nimonic' series of high-nickel alloys, originally developed for aircraft gas-turbines and still regarded primarily as aircraft materials, are now being used more widely in general engineering (e.g., where their special properties of low creep at high temperatures are of value). The principles governing successful machining of the high-nickel alloys are in general the same as those for other high-strength materials: maximum rigidity of tool and work piece, to ensure smooth cutting; tools must always be sharp, with high surface finishes and keen edges; support for the cutting edge should not be decreased by making clearance angles larger than needed; as much metal as possible should be left at the nose of roughing tools; the supply of cutting-fluid must be copious; a high, rather than a low, feed rate should be aimed at, to obviate the risk of work hardening during cutting; the maximum swarf-clearance space must be available on cutters and broaches.

In this article details are given of the machining practice developed for the 'Nimonic' alloys on the basis of these general principles. The information and data, supplied by Henry Wiggin & Company, Ltd., the manufacturers of the 'Nimonic' alloys, relate to 'Nimonic DS', 'Nimonic 75', 'Nimonic 80', 'Nimonic 80A', 'Nimonic 90', 'Nimonic 95', 'Nimonic 100', 'Nimonic 105', 'Nimocast 75', 'Nimocast 80', 'Nimocast 90', 'Nimocast 242', 'Nimocast 257', and 'Nimocast 258'.

Part I of the article covers general recommendations with respect to rake, clearance angles, high-speed tool steels, carbide-tipped tools, cutting oils and compounds, and specific recommendations on turning and boring. Part II covers recommended practice for honing, reaming, milling, drilling, and broaching.

Thermocouple System for Measurement of Turbine-Inlet Temperatures

M. E. IHNAT and W. C. HAGEL: 'A Thermocouple System for Measuring Turbine-Inlet Temperatures.'
Trans. Amer. Soc. Mechanical Engineers, Series D, Jnl. Basic Engineering, 1960, vol. 82, Mar., pp. 81–6.

The purpose of the paper is 'to report the development and evaluation of a thermocouple system for pre-turbine installation where the probe tips may reach steady-state temperatures in the range 1800°–2300°F. (980°–1260°C.), with transients up to 2500°F. (1370°C.), and the sheath or support material may be subjected to a maximum of 2100°F. (1150°C.)'.

The investigation is described in sections reporting those phases of the test programme covering work on: thermoelements; lead wire; insulation; sheath material; connectors; harness; and time-response.

It was found that platinum–15 per cent. iridium/palladium thermoelements exhibited a thermoelectric e.m.f. of 33 millivolts at 2000°F. (1095°C.), that their e.m.f. deviation did not exceed $\pm$ 0·35 per cent. during 400-hour exposure at 2300°F. (1260°C.) in a combustion atmosphere, and that a maximum time response of 1 second (at a mass flow rate of 6 pounds per second per square foot) was provided by 16-gauge inert-arc butt-welded junctions of a standard-design noble-metal combination. The authors' studies also resulted in the development, using standard foundry and fabrication techniques, of a matching nickel–4·3 per cent. silicon lead-wire alloy of the same gauge.

* Attention may be drawn to the availability of *Publn.* 1941, 'Machining Wiggin High-Nickel Alloys', issued by HENRY WIGGIN AND COMPANY, LTD. We shall be pleased to supply a free copy of this publication.

Swaged aluminium oxide was selected as the insulation material because of its high resistivity and satisfactory mechanical properties, and, on account of its high oxidation-resistance, strength and ductility, 'Inconel 702' was adopted as a suitable sheath material.

The paper includes details of an experimental harness, consisting of 6 four-contact connectors and 18 dual-junction thermocouples distributed in a 6-element compensated-ladder circuit, designed to conform to the requirements of a specific application.

Influence of Composition on the Shape of Martensite-Transformation Curves

See abstract on p. 242.

Kinetic Study of the Corrosion of Nickel in Sulphuric Acid

See abstract on p. 235.

Electrodeposition of Iron-Chromium-Nickel Alloys Approximating to the Composition of 18-8 Stainless Steels

See abstract on p. 239.

Stainless Steels: Review

Metal Bulletin of July 1960 is the second special issue of the journal to be devoted entirely to a review indicating the fields in which stainless steel is finding application, referring to developments of technical importance, and presenting, where available, data on the stainless-steel output of the main producing countries.

The review is in the form of nine feature articles, the scope of which is briefly indicated below.

Stainless Steel in the Car Industry

P. SLATER: 'Growing Consumption in Motor Cars', pp. 27–9.

The motor-vehicle industry is the largest individual consumer of stainless-steel products, both in Great Britain and in the U.S.A. Last year the American steel industry delivered 95,000 short tons of sheet and strip for this application, and, though detailed figures are not published, it is believed that consumption in the U.K. was in the region of 6,000 tons. In the U.K. the average consumption in 1959 is estimated to be about 12 lb. per car, and, even if no more stainless steel is used on individual cars, output trends indicate that total consumption will rise to 8,500 tons by 1965.

Two types of stainless steel find application in the car industry: 18-8 chromium-nickel steels, and 17 per cent. straight-chromium types. In this article notes are given on the uses to which these two grades are put in British and American cars.

Stainless Steel in Domestic Applications

'In the Home', pp. 31–3.

In this article, written by the Technical Research Staff of Firth-Vickers Stainless Steels, Ltd., a brief review is given of the development of 18-8 stainless steels, with emphasis on the introduction of stainless-steel components into domestic use (e.g., cutlery, tableware, garden implements).

Stainless Steel in Architecture

R. A. PARET: 'Elegance and Versatility in Architecture', pp. 35–9.

Notes on the uses stainless steel is finding in architecture. Photographs of actual buildings in the U.S.A. illustrate the author's notes.

Stainless Steel in Aircraft Production

'A Vital Rôle in Aircraft Production', pp. 41–4.

This short survey, prepared by Allegheny Ludlum Steel Corporation, Ltd., outlines the rôle which stainless steel is playing in solving the problems involved in high-speed flight. Particular reference is made to the properties offered by the chromium-nickel precipitation-hardenable stainless steels 'AM-350' and 'AM-355', and to the advantage which has been taken of these properties in missiles and supersonic aircraft.

Stainless Steel: World Output

World Stainless-Steel Output', p. 44.

Data are tabulated on the production, by the following countries, of austenitic and other grades of stainless steel in the years 1955–59: U.S.A., West Germany, U.K., Sweden, France, Japan, Italy.

Stainless-Steel-Clad Plate

'Clad Steels', pp. 47–9.

In this article, written by Colvilles Limited, a description is given of the process used by the Company to produce stainless-steel-clad steel plate. Reference is made to the advantages offered by, and the properties obtainable in, such plate, and the article includes notes on recommended gas-cutting, hot-working, cold-forming and welding practice.

Stainless-Steel Production in France

M. MAROY: 'The French Stainless-Steel Industry', pp. 53–60.

The author, in this survey of the French stainless-steel industry, refers, *inter alia*, to: a map indicating the main French producers of stainless steel; French sources of nickel, chromium and other relevant

alloying elements; French contributions to stainless-steel technology; production techniques (including the Ugine–Perrin process); casting, hot-rolling and sheet-rolling facilities; the rise in French stainless-steel output; and the establishment of new fields in which the various stainless steels produced find application.

Stainless-Steel Production in Japan

'A Vigorous Japanese Industry', pp. 63–5.

Prepared by the Japanese Iron and Steel Federation, this article refers to production trends and modernization developments in the Japanese stainless-steel industry, and draws attention to the firms active in this respect and to the rolling facilities available in the country.

Stainless-Steel Production in Sweden

E. ÖHMAN: 'Progress in Sweden', pp. 67–9.

The statistics presented illustrated the development of the Swedish stainless-steel industry since 1956, and highlight recent progress in the output of cold-rolled sheet and strip, tubes, atomic-energy equipment and clad steel.

Stainless-Steel Production in Italy

'Growing Production in Italy', pp. 70–1.

The article, provided by Associazione Industrie Siderurgiche Italiane, contains statistical data illustrating progress in stainless-steel production in Italy over the years 1950–58.

Stainless Steels: Fields of Application

'Stainless Steel's Varied Rôle', pp. 73–7.

Photographs and captions exemplify the uses of stainless steel in: kitchen equipment; beer barrels; wine shipment; power stations; nuclear energy.

Stainless Steels: List of Producers in Various Countries

'The World's Producers of Stainless Steel', pp. 78–85.

In the table presented, the editors have endeavoured to include the names and addresses of all the producers of stainless-steel ingots and/or semis or finished products in countries other than Communist. Listed are the names and addresses of, and the products available from, companies in: Australia, Austria, Belgium, Brazil, Canada, France, Western Germany, Italy, Japan, Norway, the Saar, Spain, Sweden, United Kingdom, United States, Yugoslavia. A number of companies producing only castings or forgings have been omitted.

Mechanism of Stress-Corrosion Cracking of Stainless Steel

D. VAN ROOYEN: 'Stress-Corrosion Cracking.'
Jnl. Electrochemical Soc., 1960, vol. 107, Aug., pp. 715–6.

According to the mechanism of stress corrosion postulated by HOAR and HINES, cracks in austenitic stainless steel initiate and propagate in purely electrochemical stages. HOAR and WEST (*Nature*, 1958, vol. 181, p. 835) concluded that anodic dissolution of stainless steel in boiling magnesium-chloride solutions is highly stimulated by the mechanically induced movement of the surface atoms, and they further reported that tests, under similar conditions, on pure-nickel specimens, gave no indication of such a mechanical effect. While it is reported that nickel and high-nickel alloys do not suffer chloride stress-corrosion cracking, it is uncertain whether the immunity of these materials arises in the initiation or in the propagation stage. Since the whole correlation between stainless steel and nickel made by HOAR and WEST is based on the assumption that cracks actually would not propagate into nickel under the conditions studied, the investigation briefly summarized in this paper was carried out to study the validity of this assumption.

Attempts were made to compare the resistance of various alloys to crack propagation with their electrochemical behaviour while corroding at high current densities in boiling magnesium-chloride solutions. Specimens were prepared by depositing a layer of a susceptible material, such as Type 304 18–8 stainless steel, onto a strip of the material to be tested, rolling the composite to the required thickness, annealing, and then subjecting it, under direct load, to the test solution contained in a glass cell. The load was high enough to cause cracks to initiate in the susceptible alloy, and the behaviour of these cracks at the boundary of the two components was then studied by metallographic examination.

Results available to date on nickel have confirmed the absence of mechanical stimulation of its anodic dissolution. Furthermore, stress-corrosion cracks which started in the Type 304 stainless-steel component of the bonded specimen proceeded to the nickel boundary and then stopped. It is deemed unlikely that a galvanic effect between the two metals could account for the stopping of the cracks at the boundary, and the results are considered to be in agreement with the electrochemical mechanism of cracking advanced by HOAR and HINES (although they do not directly constitute further proof).

Influence of Composition and Heat-Treatment on Stress-Corrosion Cracking of Austenitic Stainless Steels

E. E. DENHARD: 'Effect of Composition and Heat-Treatment on the Stress-Corrosion Cracking of Austenitic Stainless Steels.'
Corrosion, 1960, vol. 16, July, pp. 359t–69t.

Very little of the vast accumulation of data available

on the stress-corrosion characteristics of the commercial austenitic stainless steels lends itself to direct comparison, and there is no published information on the behaviour of the entire series of steels over a wide range of applied stress and under uniform and reproducible testing conditions. The influence, on stress-corrosion resistance, of small variations in the individual constituent elements of the steels has received little attention; similarly, while it has been speculated that the condition of the surface of the material prior to use might contribute to the anomalous stress-corrosion behaviour of the same grade of steel under apparently identical service conditions, study of this factor has also been neglected. The test programme now described was initiated to obtain more information on these variables. The paper is in three main sections, covering: (1) the comparative stress-corrosion resistance of commercial steels and the effect of heat-treatment and service conditions; (2) the effect of compositional variations on resistance to cracking; (3) observations on the initiation of cracking. In a concluding section the author relates his findings to some of the current theories on the mechanism of stress-corrosion cracking.

The main phases of the programme are indicated below:

(1) Initial work on a reliable standard test procedure, capable of providing reproducible results in comparative tests on a wide range of steels, culminated in the adoption of a direct-tension-type specimen on the surface of which were machined four circumferential grooves designed to introduce multiaxial stress, and so to reduce times to fracture. The specimen was loaded during exposure to boiling 42 per cent. magnesium-chloride solution (two of the notches being in the vapour phase, the other two in the liquid).

(2) Specimens of the following types of commercial steel were subjected to the accelerated-corrosion tests: A.I.S.I. Types 304, 304L, 305, 309, 310, 314, 316, 347 and 347L (i.e., 18-8, low-carbon 18-8, 18-12, 23-14, 25-20, high-silicon 25-20, 18-12-Mo, 18-10-Nb, and low-carbon 18-10-Nb types); the 25-20-Mo-Cu Steel 'Worthite'; 'Armco 17-14 Cu-Mo'; and 'Armco 17-10P'.

Specimens of Type 304 steel were evaluated after annealing at temperatures in the range 1800°-2300°F. (980°-1260°C.), and the influence of surface preparation was studied in tests on Type 304 specimens (1) as-machined, (2) machined and then either passivated, electropolished, pickled or treated to produce a black oxide coating, or (3) annealed and then either electropolished, pickled, abraded and treated to produce a phosphate film, or treated to produce a black oxide coating.

(3) The influence of variations in the carbon, nitrogen, nickel, chromium, manganese and sulphur constituents of a stable austenitic steel was assessed by stress-corrosion tests on an 18-12 basis steel whose composition was varied as shown in the table in the next column.

Elements Varied	C %	Mn %	Si %	Cr %	Ni %	N %
Control	·050	·39	·41	17·97	12·18	·059
C, N	·016	·32	·27	17·75	11·85	·032
	·047	·46	·32	17·69	12·15	·15
	·11	·40	·32	17·75	11·96	·035
	·005	·25	·13	17·59	12·29	·031
Ni	·039	·33	·33	17·70	8·11	·036
	·041	·39	·34	17·57	16·04	·042
	·041	·45	·38	17·50	20·07	·035
	·038	·55	·42	17·63	30·13	·039
	·043	·54	·74	17·64	49·92	·035
Cr	·050	·34	·20	7·93	12·07	·022
	·045	·41	·31	11·44	12·19	·025
	·042	·34	·32	15·64	12·20	·029
	·043	·33	·38	23·00	12·15	·058
Mn	·041	·10	·32	17·84	11·51	·045
	·047	1·69	·34	17·70	11·83	·040
	·043	4·92	·47	17·73	11·97	·041
Si	·041	·39	·22	17·62	12·20	·044
	·043	·55	·92	18·10	12·38	·041
	·052	·59	1·89	17·78	11·41	·048
	·044	·52	2·14	18·34	11·84	·040
	·059	·51	4·04	17·96	11·87	·031

(4) Initiation of failure, and the effects, in this connexion, of the time and temperature at which the steel was annealed, were studied in corrosion tests on Type 304 bent-beam specimens.

The data derived from the various phases of the test programme are fully discussed by the author. His main conclusions are summarized as follows:

'A test has been developed that produces accelerated and fairly reproducible results for establishing the boiling-magnesium-chloride stress-corrosion resistance of austenitic stainless steels.

'Commercial alloys tested under these conditions indicate that, where stress-corrosion cracking is a factor to be considered in their use, attention should be given primarily to the nickel content of the alloy selected. Types 310 and 314 stainless steels offer considerably greater resistance to this type of attack than do the more commonly used Types 304, 316 and 347. It is possible that, in borderline field applications, the use of the more highly alloyed grades would result in satisfactory performance, by virtue of their apparently higher threshold stress required to cause cracking.

Summary of Stress-Corrosion-Test Results
(See abstract below)

Test No.	Material	Liquid Phase		Vapour Phase	
		Cracked	Not Cracked	Cracked	Not Cracked
1	Type 347 18-8-Nb Stainless Steel	36	0	36	0
2	'Inconel'	0	36	0	36
3	Type 304 (Vacuum-Melted) Stainless Steel ..	2	20	0	22
	Type 347 Stainless Steel	14	0	14	0
4	'Croloy 16-1'	0	36	0	36
5	Nickel (Commercially Pure)	0	36	0	36
6	'Monel'	0	36	0	36
7	Titanium (Commercially Pure)	0	36	0	36
8	'Carpenter 7 Mo'	18	0	18	0
	'Carpenter 20 Nb'	0	18	18	0
9	Nickel-Plated Type 347 Steel	18	0	18	0
	Type 347 (passivated with dilute HNO_3) ..	18	0	18	0
10	S.A. 210 Carbon Steel	0	18	0	18
	'Croloy 2¼'	0	18	0	18

'No heat-treatment was found to alter effectively the stress-corrosion resistance of the commercial stainless steels, nor did varying surface conditions affect their performance under these test conditions, at least to an extent which would offer hope that alloys such as 18–8 could be protected against this form of attack.

'Nickel and silicon apparently have the most pronounced effect in inhibiting stress-corrosion cracking, whereas carbon, nitrogen, manganese and chromium exert only a minor influence.

'Stress-corrosion cracking of austenitic stainless steels appears to be of combined electrochemical and mechanical origin. The data suggest that the threshold stress required for cracking, and the overall resistance to cracking, are in some way related to the deformation characteristics of the alloy, and, to a lesser extent, its protective oxide film.'

Stress-Corrosion Tests on Materials for Steam-Generator Tubing in Nuclear-Power Plants

D. E. WHITE and E. G. JOHNSON: 'Stress-Corrosion Screening Tests of Materials for Steam-Generator Tubing in Nuclear-Power Plants.'

Corrosion, 1960, vol. 16, July, pp. 320t–4t; disc., p. 324t.

Austenitic stainless steels have been used for some time as the basic materials of construction for the primary system of pressurized-water nuclear-power plants. The choice of this type of steel is based on corrosion-resistance to the primary fluid, fabrication characteristics and nuclear-activation properties of the corrosion product. Since austenitic stainless steels have been shown to be sensitive to chloride-stress-corrosion cracking, however, the steam generator represents a potential problem area (the secondary system of a nuclear-reactor power plant is subject to the same impurities, contaminants and in-leakage as any normal boiler feed-water system: in the case of a plant using sea-water coolant, the steel is likely to be exposed to conditions conducive to stress corrosion). In anticipation of the problems that could arise from stress-corrosion cracking on the secondary side of the steam-generator tubing, the following two operations were carried out: (1) evaluation of chemical inhibitors for addition to the secondary-side (boiler) water (see abstract in *Nickel Bulletin*, 1959, vol. 32, No. 12, p. 375); (2) evaluation of alternative materials not subject to chloride-stress-corrosion cracking. This paper is concerned with an investigation based on the second approach.

Stressed U-bend specimens of likely materials were exposed, for 24 hours at 500°F. (260°C.) in a tilting autoclave (i.e., for 144 complete tilt cycles), to both the liquid and vapour phases of a synthetic boiler-water solution (pH 10·6–11·2) containing oxygen, phosphate and 500 p.p.m. of chloride ion. The materials tested and the results obtained are summarized in the table reproduced above.

'Inconel', 'Monel', nickel and titanium, which are recommended for further study in model-boiler

Composition of Steels subjected to Atmospheric Stress-Corrosion Tests

(See abstract below)

Steel	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	V %	Ti %	N %	Al %	W %	B %
'USS Airsteel X200'* ..	0·39	0·93	0·009	0·014	1·51	—	2·00	0·48	0·07	—	—	0·04	—	—
'USS Strux'	0·38	0·87	0·010	0·008	1·45	0·60	0·82	0·52	0·05	0·03	—	—	—	0·001
'MBMC No. 1'	0·43	0·92	0·011	0·015	1·35	—	0·69	0·03	0·07	—	—	—	—	—
A.I.S.I. 4340	0·39	0·79	0·014	0·019	0·25	1·78	0·79	0·25	0·005	<0·005	0·010	0·06	—	—
A.I.S.I. 4130	0·25	0·50	0·006	0·011	0·22	0·01	0·95	0·19	<0·005	<0·005	—	0·033	—	—
A.I.S.I. 4335+V ..	0·35	0·75	0·005	0·012	0·23	1·42	0·68	0·32	0·20	—	—	—	—	—
Hot-Work Die Steels:														
Type A*	0·45	0·60	0·011	0·017	0·68	0·34	5·09	1·17	0·52	—	—	—	—	—
Type B	0·47	0·59	0·003	0·016	0·72	0·42	5·30	1·73	0·26	—	—	—	0·99	—
Type C	0·53	0·50	0·002	0·017	1·08	1·50	5·33	1·80	0·96	—	—	—	—	—
'USS 12MoV' Stainless Steel*	0·25	0·50	0·019	0·015	0·45	0·63	12·16	0·98	0·33	—	—	—	—	—
'USS Stainless W'* ..	0·081	0·73	0·015	0·013	0·78	6·66	16·72	0·21	—	0·90	0·034	0·24	—	—
Precipitation-Hardenable Steels:														
Type A*	0·076	0·65	—	0·009	0·36	7·17	16·89	—	—	0·007	—	1·22	—	—
Type B	0·072	0·68	—	—	0·32	6·94	14·79	2·47	—	0·063	—	1·13	—	—
'USS 17-5MnV' Stainless Steel	0·11	13·50	0·019	0·012	0·70	4·61	16·19	2·00	0·92	—	0·36	—	—	—
'USS Tenelon' Stainless Steel	0·096	15·10	0·022	0·008	0·50	0·43	17·96	—	—	—	0·46	—	—	—
Stainless Steels:														
A.I.S.I. Type 201 ..	0·10	7·73	0·029	0·021	0·33	4·60	16·53	—	—	—	0·16	—	—	—
A.I.S.I. Type 202 ..	0·12	7·54	0·043	0·009	0·46	4·58	17·90		—	—	0·16	—	—	—
A.I.S.I. Type 301 ..	0·09	1·24	0·026	0·018	0·50	6·98	17·56	—	—	—	—	—	—	—

* More than one heat of steel tested.

tests, were completely free from cracking or pitting. Their surfaces were covered with a light oxide tarnish film.

'Croloy 16–1' showed no sign of stress-corrosion cracking, but did exhibit considerable pitting; it is emphasized, however, that the attack on 'Croloy 16–1' specimens was not as severe as that observed on either the SA-210 carbon steel or 'Croloy 2¼'. It is deemed reasonable to expect that 'Croloy 16–1' would perform satisfactorily under conditions in which the oxygen was held to those lower levels found in normal boiler operation, and this material is also recommended for further study.

The vacuum-melted Type 304 chromium-nickel stainless steel was of extra-low carbon and nitrogen content, and, as a result, contained from 10–15 per cent. ferrite. In the 44 specimens tested, only two very small cracks were observed, though it was not known whether the superior resistance of this alloy to chloride stress corrosion could be attributed to the presence of ferrite in the structure or simply to the 'cleanliness' of the alloy due to vacuum melting.

Nickel-plated Type 347 niobium-stabilized 18–8 stainless steel was included in the test series on the assumption that the nickel deposit might protect the basis metal from stress-corrosion cracking. It became clear, however, that the achievement of a defect-free coating throughout a full-size steam generator was impracticable, and that the only chance of the coating's being completely effective would be if it were anodic to the substrate. To examine this feature, defects, in the form of ground spots and bed fissures, were introduced into the stressed portion of the specimens. Since cracking occurred on all of the specimens under the plating near the fissures, it was assumed that nickel plating did not provide anodic protection.

Atmospheric-Stress-Corrosion Tests on Steels for Aeronautical Applications

E. H. PHELPS and A. W. LOGINOW: 'Stress Corrosion of Steels for Aircraft and Missiles.'

Corrosion, 1960, vol. 16, July, pp. 325t–34t; disc., pp. 334t–5t.

The purpose of this paper is to present the results of atmospheric and laboratory stress-corrosion tests on ultra-high-strength steels intended for use in aeronautical and missile applications. The steels studied (see compositions in table above) covered

the five main classes employed in such applications: (1) low-alloy steels, (2) 5 per cent. chromium hot-work die steels, (3) 12 per cent. chromium martensitic stainless steels, (4) semi-austenitic precipitation-hardenable steels, (5) cold-worked austenitic stainless steels.

Specimens were sheared from sheet stock, heat-treated to obtain the desired properties, and, after de-scaling and de-greasing, were stressed by being bent into a holder in the test rack. The atmospheric-corrosion sites were at Kure Beach (a very corrosive environment involving exposure to sea-water spray) and Monroeville, Pa. (a moderately corrosive semi-industrial environment). With a few exceptions, the yield strengths and tensile strengths of the steels were higher than 200,000 p.s.i. (89·5 t.s.i.; 140·5 kg./mm.^{2}). A specimen was considered to have failed if it fractured or if a crack was visible to the naked eye.

Included in the investigation were tests designed to take account of the following factors: the effect of the stress level; the influence of corrosion on mechanical properties; the inhibitive effect of protective coatings (e.g., paint, chemically-deposited or electrodeposited nickel, chromium deposits, nickel-cadmium coatings, rust-preventive grease, zinc-dust dibutyl titanate); the effect of the tempering temperature. The '12 MoV' stainless steel was subjected to laboratory humidity tests in an attempt to throw light on the mechanism of the stress corrosion observed, and cracked specimens of steels exposed at Kure Beach were metallographically examined.

The results demonstrate that steels hardened by heat-treatment to high strength levels are, under certain conditions, susceptible to atmospheric-stress-corrosion cracking. Cold-worked and stress-relieved austenitic stainless steels exhibiting very high yield and tensile strengths were, however, resistant to such attack at Kure Beach, and the semi-austenitic precipitation-hardenable stainless steels exhibited similar resistance to stress corrosion at Monroeville.

Generally the time to failure of the susceptible steels increased when the stress level was decreased from 90 to 50 per cent. of the yield strength, but the failure time exhibited by some steels was about the same at stress levels of 50, 75 and 90 per cent. of the yield strength. The yield and tensile strengths of several steels were not affected by corrosion during 6 months' exposure at Kure Beach (the ductility of steels with chromium contents of 12 per cent. or less was, however, decreased by this exposure). An alloy steel and a 12 per cent. chromium martensitic steel were resistant to stress corrosion when tempered at 1100° and 1200°F. (595° and 650°C.), and the stress-corrosion resistance of hot-work die steels tempered at 1100°F was much greater than that of specimens tempered at 1000°F. (540°C.).

The results of laboratory tests on the martensitic stainless steel showed that environment is one of the controlling factors in the failures observed, and that anions other than chloride can cause cracking. Data derived from experiments on the mechanism of cracking indicate that stress corrosion of a 12 per cent. chromium martensitic stainless steel was a consequence of corrosion along an active path in the steel, and not the result of hydrogen induced in the metal by corrosion.

The study carried out on protective coatings suggests that those anodic to steel effectively prevent stress corrosion.

It is emphasized that no correlation has been established between the test data and service performance: the results should be regarded only as a guide to the use of the steels in aeronautical applications.

Resistance of Nickel-containing Materials to Corrosion by Brine

J. M. TURNBULL: 'Salt-Refinery Corrosion Caused by Varying Evaporator Conditions.'
Corrosion, 1960, vol. 16, July, pp. 11-12, 14, 16.

The high rate of corrosion experienced in plant (particularly in heat-exchanger tubes) producing sodium chloride by brine evaporation led to the initiation of a series of tests (described by the author) to determine, on the basis of corrosion-resistance and economic considerations, the most suitable materials of construction.

At the refining plant, evaporation of sodium-chloride brine is achieved by the multiple-effect system, in which vapour from each preceding effect is used to heat brine in the following effect at a reduced pressure. Four effects are used to evaporate the brine, which is circulated from the vessels through external heat-exchangers by axial-flow pumps; the same circulation agitates the brine in the vessel. Two grades of salt are produced at the refinery in question:

(1) Standard evaporated salt, manufactured by evaporation of an almost neutral brine (pH ~7·5) containing calcium chloride, magnesium chloride and sodium chloride in solution. Suspended in the brine are crystals of calcium sulphate and sodium chloride.

(2) A highly purified salt, produced by evaporation of a highly alkaline brine (pH >12) containing sodium sulphate, sodium carbonate, sodium hydroxide and sodium chloride in solution. The crystallized salt in suspension is approximately 25 per cent. of that suspended in the standard brine.

Two series of tests were carried out. The first involved exposing test specimens in the first effect; in the second series, the influence of temperature was taken into account by exposing the specimens in all four effects (the temperature of the standard and alkaline brines in the individual effects was, respectively, (1) 225°, (2) 185°, (3) 158°, (4) 104°F. and (1) 208°, (2) 169°, (3) 135°, (4) 92°F. The compositions of the materials evaluated are noted in the table on p. 258.

Corrosion rates and corrosion behaviour are discussed in relation to the light they throw on the

Nominal Composition of Materials Tested in Brine

(See abstract, p. 257)

Material	Ni %	Cu %	Cr %	Si %	Mo %	Fe %	C %	Mn %	Sn %	Others %
'S Monel', Cast	63	30	—	4	—	2·0	0·1	0·75	—	—
'Monel', Cast	63	32	—	1·6	—	1·5	0·15	0·75	—	—
'Monel', Wrought ..	67	30	—	0·1	—	1·4	0·15	1·00	—	—
90 Copper-10 Nickel ..	10	90	—	—	—	0·7	—	0·2	—	—
90 Copper-10 Nickel ..	10	90	—	—	—	1·2	—	0·3	—	—
70 Copper-30 Nickel ..	30	70	—	—	—	0·5	—	0·3	—	—
Copper	—	99·9	—	—	—	—	—	—	—	—
Phosphor Bronze	—	89·75	—	—	—	—	—	—	10	P 0·25
'Carpenter 20'	29	3	20	1	2	Bal.	0·07	0·75	—	Nb 8 × C
Type 316 Steel	10-14	—	16-18	1	2-3	Bal.	0·1	2·0	—	—
'Worthite'	24	1·75	20	3·5	3·0	Bal.	0·07	0·6	—	—
'Inconel'	72	0·5	14-17	0·5	—	6-10	0·15	1·0	—	—
'Ni-Resist 2'	18-22	0·5	2·0	1-2	—	Bal.	3	1·0	—	—
Aluminium-Bronze ..	5	82	—	—	—	2·5	—	—	—	Al 9·5
'Hastelloy C'	Bal.	—	15-18	1	16-18	4·5-7	0·15	1	—	W 4·0
Nickel	99·4	0·1	—	0·05	—	0·15	0·05	0·25	—	—
'Incoloy'	30-34	0·3	19-22	1	—	Bal.	0·1	1·5	—	—
'Everdur'	—	96	—	3	—	—	—	1	—	—
Titanium	Specific Alloy Unknown									
'Carpenter 7 Mo'	4	—	26-28	—	1·5	Bal.	—	—	—	—

suitability of the various classes of material for refinery service. Reviewing this evaluation the author comments:

'These coupon tests point out that there is no economically perfect answer to the corrosion problem. Suitable metals suffer corrosion in this service, either standard or alkaline. It is necessary to balance the corrosion rate against the cost to make the best selection. In general, the copper alloys offered excellent protection from crevice corrosion, especially the 90 per cent. or higher copper alloys. Stainless alloys and higher-nickel-content alloys had more severe crevice corrosion. In cases where proper design cannot be used to eliminate stagnant areas (gaskets, etc.), use of these alloys should be eliminated.

'Stainless alloys of the 300 series should be avoided in brine usage where temperatures higher than 150°F. (65°C.) are encountered. The use of 316 stainless steel in temperatures below 150°F. should be watched very carefully. The Type 316 coupons were not exposed long enough to determine if 316 stainless would be adequate at the lower temperatures. The use of 316 in ambient brine has been successful and the material offers excellent resistance to erosion attack. Stress corrosion is always a possibility, even at these low temperatures. 'Carpenter 20' offers good service, but, because of the many pits evidenced in the coupons, should be used with caution, especially in the hot effects. 'Worthite' has been used for years in ambient brine and salt with excellent results. However, caution should be used in its exposure to hot brine in alkaline service.

'The cause of accelerated attack by high alkaline brine on 'Inconel', 'Worthite' and 316 stainless is not known, but there is no doubt that attack on these three alloys is greatly accelerated by the brine.

'Previous tests showed 'Incoloy' and 'Carpenter 7 Mo' also had accelerated attack in alkaline service. No proven reason can be given for the greater corrosion rates of the high-copper alloys. A possible explanation might be that the film produced in alkaline service is much less adherent or softer, and is hence removed by erosion of the salt crystals more readily than the film developed in standard service.

'Use of 70 copper-30 nickel alloy offers an economical answer to alkaline service, comparing favourably with 'Monel', but in standard service 'Monel' has a definite edge. 'Monel', in general, offers good

protection against stress corrosion and fair protection against erosion. Although it has definite faults, 'Monel' is the closest to an all round answer to the corrosion problem in brine service.

'In heat-exchanger tubes the 70 copper-30 nickel alloy would be excellent in alkaline service and good in standard brine. On an over-all basis, considering corrosion and costs, 70-30 would seem to be the best alloy for tube service in most neutral or alkaline brine conditions.'

Use of Nickel and Nickel-base Alloys for Chemical Plant

J. HINDE: 'Materials of Construction for Chemical Plant: Nickel.'

Chemical and Process Engineering, 1960, vol. 41, July, pp. 295, 297-9, 301-3.

The combination of high corrosion-resistance and excellent mechanical properties offered by nickel and nickel-base alloys has long been used to advantage in the chemical industry, and for many applications nickel-containing materials have proved irreplaceable. In this article the author reviews the properties of the principal classes of alloy employed in the petrochemical field, and comments upon the relevant features (in particular, resistance to specific corrosive media) which render each class of value to the materials engineer.

The review is in six sections. The first five cover the properties and general applications of, respectively, commercial nickel, nickel-copper alloys (as represented by 'Monel'), nickel-chromium-iron alloys ('Inconel'), nickel-molybdenum alloys (e.g., 'Hastelloy B' and 'Corronel 210'), nickel - molybdenum - chromium alloys (e.g., 'Hastelloy C') and nickel-molybdenum-chromium-iron alloys 'Ni-O-Nel' and 'Hastelloy F').

In the final section the author briefly notes the fields in which each class of material has been used to optimum advantage.

Properties of Steels Resistant to High-Pressure Hydrogen

I. CLAAS: 'Present State of Knowledge of the Properties of Steels Resistant to High-Pressure Hydrogen.'

Stahl u. Eisen, 1960, vol. 80, Aug. 18, pp. 1117-35.

A great many industrial syntheses are carried out in the presence of hydrogen, frequently at high pressures and temperatures (up to 1000 atm. and 600°C.). This review of information available on the development and properties of steels resistant to high-pressure hydrogen, and therefore suitable for use in plant handling high-pressure hydrogen (e.g., hydrogenation plant), is based on a *bibliography* of 94 items. The main emphasis is placed on steels covered by the German Iron and Steel Material Specification 590 (*Stahl-Eisen Werkstoffblatt* 590-51), but consideration is also given to relevant data on austenitic and other types of high-alloy steel.

In the introductory section of the review, the physico-mechanical processes involved in the action of hydrogen on steel are discussed, account being taken of the influence of time and temperature. Subsequent sections are concerned with the heat-treatment, welding, fabrication, mechanical properties (including creep-resistance) and structure of the steels covered. Tests to determine the suitability of steel for service in the presence of high-pressure hydrogen, and operational experience gained in the application of such steels, form the subjects of the concluding sections of the review.

Electrolytic Etching of Multiphase Iron-Chromium-Nickel Alloys in Caustic-Soda Solution

W. SCHAARWÄCHTER, H. LÜDERING and F. K. NAUMANN: 'Electrolytic Etching of Multiphase Iron-Chromium-Nickel Alloys in Caustic-Soda Solution.'

Archiv f.d. Eisenhüttenwesen, 1960, vol. 31, June, pp. 385-91.

The deleterious effects of σ phase on the properties of straight-chromium and chromium-nickel steels prompted the authors to investigate the feasibility of developing an etching technique capable of revealing the individual phases, and particularly the σ phase, by electrolytic etching in 10*N* sodium-hydroxide solution.

Using the current-density/potential curves determined for a range of iron-chromium-nickel alloys, the rates of dissolution of the individual phases of a multiphase alloy were determined as a function of the potential of the specimen. From the data obtained, optimum conditions were established both for electrolytic etching using a potentiostat, and for etching with Redox systems.

It was found that in 10*N* caustic soda the dissolution rate of the alloys in the transpassivity region increased with increase in chromium content and decreased with increase in nickel content. Four potential regions, associated with differences in etching behaviour, were determined during etching. Since, for optimum results in etching, the potential of the specimen must be maintained within the desired region, electrolytic etching, using an electronic potentiostat, is regarded as the most reliable procedure.

Good results were also obtained by etching at room temperature in a solution of 4 g. of potassium permanganate and 40 g. of sodium hydroxide in 100 ml. of water.

Determination of the dissolution rates of the same range of alloys in 16 per cent. sulphuric acid showed that, in the transpassivity region, the rate increased with increase both in the nickel and the chromium content, an effect which would adversely influence the results obtained during etching.

Influence of Phosphorus on the Weldability and High-Temperature Strength of Low-Carbon Stainless Steels

G. R. RUNDELL and R. J. RAUDEBAUGH: 'The Effect of Phosphorus on the Elevated-Temperature Strength and Weldability of Some Low-Carbon Austenitic Stainless Steels.'

Amer. Soc. Metals, 1960, *Preprint* 194; 18 pp.

Hot cracking of Type 347 (niobium-stabilized) stainless steel employed in welded structures at

elevated temperatures has been recognized as a major fabrication problem. Since the use of unstabilized low-carbon (0·03 max. per cent.) grades of austenitic stainless steel would not only obviate such welding problems, but also prevent carbide precipitation, the investigation described was carried out to develop a solution-strengthened low-carbon Type 304 stainless steel, suitable for use at super-heated-steam temperatures (1200°F.: 650°C.). The steel was to have a stress-rupture strength at 1200°F. equal to, or exceeding, that of Type 347, and be capable of being welded in heavy sections. Work was to be carried out also on Type 316 stainless steel, with the aim of similarly strengthening this grade.

The investigation involved study of the effects of a range of alloying elements (e.g., nitrogen, tungsten, copper, silicon, vanadium, phosphorus), and, of these, phosphorus was found to be the most effective strengthener. The present paper describes the influence of additions of up to 0·62 per cent. phosphorus on the strength of low-carbon (0·03 max. per cent.) stainless steels of A.I.S.I. Type 304, 310 and 316 austenitic steels. The weldability of Type 304 and 316 steels was studied as a function of a phosphorus addition of 0·03 per cent.

The compositions of the steels studied are listed below:

Type	C %	N %	Si %	Mn %	Cr %	Ni %	Mo %	P %
304	0·028	0·038	0·58	1·46	18·4	9·5	—	—
304	0·031	0·12	0·64	1·31	18·5	9·2	—	0·11
304	0·029	0·105	0·59	1·30	18·5	9·1	—	0·20
304	0·021	0·042	0·67	1·42	18·6	9·4	—	0·34
304	0·027	0·025	0·64	1·50	18·1	9·5	—	0·46
310	0·031	0·026	0·64	1·47	25·1	19·8	—	0·31
316	0·022	0·028	0·48	1·08	16·1	11·9	2·35	0·015
316	0·017	0·013	0·46	1·14	16·4	12·1	2·34	0·12
316	0·019	0·021	0·55	1·18	16·0	11·9	2·34	0·23
316	0·020	0·020	0·50	1·07	16·5	12·0	2·50	0·29
316	0·017	0·020	0·43	1·21	16·1	11·8	2·28	0·53
316	0·015	0·021	0·51	1·09	16·0	11·7	2·43	0·62

The steels were evaluated by stress-rupture tests at 1200°F. (650°C.), short-time tensile tests at 75°, 900°, 1200° and 1500°F. (25°, 480°, 650° and 815°C.), and, in the case of Types 304 and 316, weldability and hot-ductility tests.

The investigation demonstrates that all three low-carbon grades may be considerably strengthened, for use at 1200°F., by the addition of phosphorus: although the yield and ultimate strengths were increased at other temperatures, maximum improvement occurred at that temperature. The stress-rupture ductility of Type 304 stainless steel at 1200°F. was reduced by addition of phosphorus, but phosphorus-containing Type 316, stainless steel maintained a much higher degree of ductility. No significant reduction in the ductility of either type of phosphorus-bearing steel was observed in short-time tensile tests.

The weldability tests demonstrated that phosphorus-containing steels are satisfactorily weldable, provided that their carbon content is maintained below 0·03 per cent. and that the nickel content is kept on the low side of the range. This finding is explained in terms of the relationship between composition and delayed solidification over a wide range of temperature.

Notch-Rupture Strength of the Heat-Affected Zone of 18-8-Nb Weldments

R. J. CHRISTOFFEL: 'Notch-Rupture Strength of Type 347 Heat-Affected Zone.'

Welding Jnl., 1960, vol. 39, July, pp. 315s-20s.

The investigation described by the author has been previously reported in a paper to the American Society of Mechanical Engineers: see abstract in *Nickel Bulletin*, 1960, vol. 33, No. 4, pp. 93–4.

CO_2 Welding of Nickel-containing Sheet Materials

A. G. BRAIN and A. A. SMITH: 'CO_2 Welding of Sheet Materials.'

Brit. Welding Jnl., 1960, vol. 7. July, pp. 463–71.

Previous experience has indicated that, during welding by the CO_2-shielded metal-arc process, metal transfer across the CO_2-shielded steel arc occurs in a coarsely globular form (unlike the fine regular spray-type transfer which defines the useful welding-current range with other gas/metal combinations such as aluminium in argon). At the necessarily low currents required for the welding of thin-gauge steel sheet, it was to be expected that infrequent transfer of coarse droplets would occur across the CO_2-shielded arc, resulting in an irregular bead and non-uniform penetration. The weld appearance would also be marred by the occurrence of spatter, which was another observed feature of the process.

In the initial phase of the investigation reported, a study was therefore made of the factors affecting metal transfer in CO_2 (it was thought that the characteristics of weld beads could be correlated with metal droplet size and transfer frequency). In an attempt to establish satisfactory welding conditions for steel sheet, the influence of welding current, diameter of the wire, and arc voltage was investigated using mild-steel and stainless-steel wire. It was found that, at low currents, optimum metal transfer and weld-bead quality were obtained using a low-voltage short-circuiting arc. These conditions were then applied in the CO_2-shielded welding of sheet in A.I.S.I. 4130 chromium-molybdenum low-alloy steel, 'Fortiweld' molybdenum-boron low-alloy bainitic steel, En58B chromium-nickel austenitic steel, and the nickel-base heat-resisting alloys 'Nimonic 75' and 'Nimonic 90'. Welding conditions are outlined, and data are presented on weld properties and the transfer efficiency of the constituent elements of the electrode wire.

At the low currents (<200 amp.) employed in thin-gauge welding, use of a rapidly-short-circuiting arc, at 18–20 v., was found necessary to ensure production of weld beads of good shape and appearance, welding conditions which may be obtained using a constant-potential power source of suitable dynamic characteristics.

Welds in the low-alloy steels exhibited satisfactory joint strength. The transfer efficiency of the elements nickel, chromium, molybdenum and boron across the arc was high and not very different from that in argon/5 per cent. oxygen; severe element loss was confined to the deoxidizers silicon and manganese. The principal difficulties encountered were the 'peaky' nature of the bead and the occurrence of undercutting at welding speeds of about 25 in./minute (62·5 cm./minute). Reduction of the weld-pool length might, it is considered, result in an improvement in weld contour, and the possibility of welding slightly downhill is deemed worthy of investigation in this connexion.

Welds in the austenitic stainless steels studied exhibited excellent bead shape and appearance, and possessed a high degree of freedom from undercutting. The transfer efficiency of chromium and nickel across the arc was high, but that of the ferritizing and stabilizing elements silicon and niobium was lower. Carbon absorption occurred, but its effect, and the element losses, were minimized by the considerable dilution with fused sheet material.

Since the electrode metal was subjected to appreciable oxidation, carbon dioxide is, it is concluded, apparently not an ideal shielding medium for alloys of the 'Nimonic' series. The oxidation products were unfused and formed a scum on the weld pool, reducing its fluidity and causing irregularly-shaped bead formation. Welding in this gas is nevertheless possible, and the composition of metal transferred across the arc was not markedly different from that of the original wire.

PATENTS

Ring-Shaped Ferromagnetic Cores

A ferromagnetic ring-shaped core exhibiting a rectangular hysteresis loop is produced from nickel-zinc or magnesium-zinc ferrites by a process which involves: (1) mixing iron oxides with nickel and zinc oxides, or zinc and magnesium oxides, in amounts delimited in accompanying ternary diagrams; (2) adding 0·1–5 wt. per cent. of cobalt oxide; (3) grinding and screening the mixture; (4) compacting; (5) sintering at a temperature above 1000°C.; (6) slowly cooling to room temperature over a period of at least 12 hours, or rapidly cooling and then reheating to about 600°C. and slowly cooling to room temperature over at least 12 hours; (7) subjecting the sintered body to a longitudinal magnetic field (as defined in the patent) during cooling to room temperature.

STEATIT-MAGNESIA A.G. and
STEATITE RESEARCH CORPORATION.

Brit. Pat. 846,274.
Similar to French „ 1,159,399.

Powder-Metallurgical Production of Nickel Strip

In a method of producing metal strip from powder, the powder is fed downwards to the nip between a pair of cylindrical rolls mounted upon horizontal axes, and, in passing through the nip, is formed into a continuous strip. The compacted strip is sintered and the sintered strip is then cold-rolled. The main feature of the invention is that the powder is fed to the compacting rolls such that the amounts delivered to the centre are proportionately greater than those at the sides. This extra initial supply of powder in the centre of the strip compensates the powder's tendency to be forced outwards during compacting, and avoids the formation of zones of high density along, and thus prevents frilling of, the edges of the strip.

The invention is exemplified in the patent in relation to the production of $5\frac{3}{4}$-in.-wide (14·3-cm.-wide) strip from carbonyl-nickel powder.

MOND NICKEL COMPANY, LTD. (inventors, A. R. BOUGHTON, D. K. WORN and R. P. PERKS).

Brit. Pat. 842,443.

Production of Nickel Oxide

Nickel-oxide powder, suitable for use in ferrites, is produced, without sintering, by roasting in air a powder mixture of nickel and nickel oxide (the nickel oxide preferably comprising 30–50 per cent. of the mixture) until substantially all the nickel is converted to oxide. Inclusion of nickel oxide in the mixture ensures the substantial absence of free metal in the product. The nickel-powder constituent is preferably produced by thermal decomposition of nickel carbonyl, and is in the form of aggregates with a structure resembling cotton wool.

MOND NICKEL COMPANY, LTD.
(inventors, D. M. LLEWELYN and D. H. WEST).

Brit. Pat. 845,464.

Improved Insulin Preparations

In the treatment of diabetics, it is possible, by administering insulin in combination with glucagon, to place a larger quantity of glucagon at the disposal of the organism without the blood sugar content's rising to such an extent that a great part of the glucose is secreted again. Previously this effect could be attained only by administering a mixture of insulin and glucagon by means of a prolonged intravenous infusion. In accordance with the present invention, a process has been found for the production of an injectable preparation which contains glucagon in addition to insulin. The preparation comprises insulin, glucagon, and at least one of the metals zinc, cobalt, nickel, copper, manganese, aluminium and iron. The glucagon is present in a quantity at least 1 wt.

per cent. of the insulin, and the metal is present in a quantity at least 0·3 milligram equivalent per gram of the combination of insulin and glucagon. The pH of the preparation is adjusted to between 2 and 9.

The mixture of insulin and glucagon is insoluble in aqueous media at physiological pH, and therefore both the insulin and the glucagon have prolonged activity. It is suggested as probable that, in the precipitates of the mixture of insulin and glucagon, the molecules of the two substances are linked together by means of metal atoms.

N. V. ORGANON. *Brit. Pat.* 844,434.

Nickel-containing Preservative for Textiles, Wood or Paper

Copper, nickel and zinc pentachlorophenates are very insoluble and, while possessing excellent preservative properties, have found little use as preservatives for textiles and wood, because they could not be economically incorporated in sufficient quantities by any of the known methods. According to the claims of the present patent, fibrous cellulosic materials, such as textiles, wood and paper, are preserved from the attack of fungi, insects and other organisms by impregnation with an aqueous solution of (1) a water-soluble salt of a polychlorophenol, (2) a tetra-alkali metal pyrophosphate, and (3) a salt of a metal (preferably copper, nickel or zinc) having a specific gravity greater than four. On impregnation, and during the drying process, the metal ions are stated to react with the polychlorophenate ions to precipitate the respective heavy-metal polychlorophenates within the interstices of the impregnated materials.

MONSANTO CHEMICAL COMPANY. *Brit. Pat.* 843,839.

Hermetically Sealed Nickel-Cadmium Flashlight Battery

In charging storage batteries, the last stages of the procedure are associated with the liberation of hydrogen and oxygen at the electrodes, an effect which causes serious disadvantages in storage batteries of the sealed type. According to the present invention, an alkaline rechargeable nickel-cadmium flashlight battery, which is reliable even after prolonged over-charging, consists of (1) a circular, thin hermetically sealed stainless-steel can; (2) closely packed cell elements consisting substantially of rectangular thin flat nickel and cadmium electrodes separated by rectangular thin flat and at least semi-permeable separators; (3) a spongy nickel, platinum or iridium structure within the cavities left between the cell elements and the inner walls of the can. The spongy-metal structure is structurally independent from, but in direct electrical contact with, the cadmium electrodes and the stainless-steel can, and the alkaline electrolyte is absorbed by the separators to such an extent that only a small excess of electrolyte is present to wet the free surface of the spongy-metal structure, and the oxygen formed during charging is permitted to pass through freely.

H. J. MANDEL, assignor to U.S. SECRETARY OF THE ARMY. *U.S. Pat.* 2,941,022.

Sealed Alkaline Storage Batteries

The sealed alkaline-type storage battery covered by the patent comprises a container, a quantity of electrolyte, and positive and negative electrodes, the former electrode having a charge capacity greater than that of the latter (which contains a reserve of uncharged active material). Preferably the positive electrode contains an active material consisting of nickelic hydroxide, and the negative contains an active material of cadmium with an uncharged reserve of cadmium hydroxide; the nickelic hydroxide is capable of delivering a greater amount of electrical energy than the cadmium. The imbalance resulting from this arrangement obtains during the life of the cell and prevents the evolution of hydrogen by ensuring that the negative plate is not overcharged, and that (1) the positive plate will not be reversed or (2), should reversal be encountered, there will be a reaction of oxygen absorption which will be preferential to the evolution of hydrogen.

ELECTRIC STORAGE BATTERY COMPANY.
Brit Pat. 845,996.

In a sealed alkaline storage battery the positive and negative plates are provided with gas passages which enable the gas evolved at a positive plate readily to make contact with the active material of a negative plate. This construction facilitates recombination of gases, and prevents dangerous pressure build-up due to gas evolution. The invention is exemplified in the patent in relation to a drawing of a sealed battery incorporating negative and positive plates of porous sintered nickel impregnated with, respectively, metallic cadmium and nickelic oxide.

ELECTRIC STORAGE BATTERY COMPANY.
Brit. Pat. 846,010.

Single-Coat Vitreous Enamelling of Steel

The method of pretreating an iron or steel basis metal to which the patent relates is stated to ensure the production of an adherent vitreous-enamel coating of good appearance and to obviate the need for a ground coat.

The pretreatment involves: (1) applying an oxide coating which comprises one or more of the following: titanium dioxide, antimony oxide, tungsten oxide, molybdenum oxide or anhydride, or mixtures of molybdenum oxide with nickel oxide or cobalt oxide or both; (2) heating the oxide-coated basis metal, in a substantially non-oxidizing atmosphere, to a temperature at which the oxide is reduced by reaction with the iron in the substrate (thereby diffusing the surface of the basis metal with, as the case may be, titanium, antimony, tungsten, molybdenum, molybdenum+nickel, molybdenum+cobalt, or molybdenum+ nickel+cobalt).

It is hypothesized that the oxidation of the iron in the substrate is controlled by the antimony, tungsten or molybdenum formed on, or diffused into, the basis metal. Fe_2O_3, which is not soluble in the iron and is therefore detrimental to adhesion, is prevented

from forming during firing, but Fe_3O_4, or preferably FeO, are present to ensure an adequate bond. A cover coating of light-coloured vitreous enamel, substantially free from dark-coloured adherence-promoting oxides, is then applied and fired.

INLAND STEEL COMPANY. *Brit. Pat.* 843,890.

Direct Bonding of Vitreous Enamel to Steel

Due to the lack of adherence between the coating and the steel, and as a result of the formation of hydrogen defects in the coatings during or after firing, it has, in the past, proved impossible to apply white or light-coloured glass coatings as a single coat directly to carbon steel. The invention claimed is based on the finding that application of a nickelous-oxide coating to the steel surface prior to glassing eliminates hydrogen defects in the glass coating and substantially increases the adherence of the glass to the steel.

The steel basis metal (carbon content preferably <0·3 per cent.) is cleaned, and sprayed with an aqueous suspension of nickelous oxide (particle size <200 mesh) to achieve a concentration of 0·1–1 g. of dry nickelous oxide per sq. ft. of steel surface. This intermediate coating is dried, and a light-coloured vitreous-enamel frit is applied to the coated steel and fired. It is believed that the layer of nickel-oxide particles react with the hydrogen evolved during firing and prevent 'fishscaling'.

J. D. SULLIVAN, assignor to A. O. SMITH CORPORATION.
U.S. Pat. 2,940,865.

Deposition of Nickel viâ Nickel Carbonyl

A component is gas plated with nickel by a method which, stated to be satisfactorily practical and capable of producing deposits of closely controlled thickness and of good quality and appearance, involves heating the component, in an atmosphere containing nickel-carbonyl vapour, to a temperature at which the nickel carbonyl decomposes, while maintaining the pressure of the nickel carbonyl below 100 mm. (and, preferably, at 1–3 mm.) of mercury. The preferred application is to the nickel plating of uranium.

U.K. ATOMIC ENERGY AUTHORITY (inventor, L. W. OWEN).
Brit. Pat. 843,531.

Improved Chemical Nickel-Plating Solution

During chemical nickel plating from solutions of the nickel-cation/hypophosphite-anion type there is a tendency for some of the nickel to be lost due to limited reduction of nickel ions within the solution itself (a phenomenon which is manifested by the accumulation of small flakes of nickel-phosphorus alloy on the surface of the metal being plated). The present invention is based on the finding that incorporation of two or more cations of elements of Group VB of the periodic system not only stabilizes such solutions against spontaneous and random reduction of nickel in the bath, but also increases the plating rate.

The nickel-cation/hypophosphite-anion plating solution covered by the patent contains an aggregate amount of 0·1–100 p.p.m. by weight of at least two of the elements arsenic, antimony and bismuth, the ratio of one of the elements to the other, or to each of the other elements, ranging from 1:5 to 1:0·5.

REYNOLDS METALS COMPANY.
Brit. Pat. 845,648.
Similar to U.S. „ 2,884,344.

Chemical Nickel Plating of Large-Scale Components

The chemical-nickel-plating system covered by the patent is intended to provide a means of plating, on an industrial basis, such large-scale components as railway tank cars. The system, involving the continuous circulation of a large volume of an aqueous plating solution, incorporates improved facilities for cooling and heating the plating solution (at, respectively, the storage and plating stages of the process), which increase the efficiency of operation and minimize the risk of spontaneous decomposition.

Diagrams illustrating the salient features of the invention are fully discussed in the preamble of the patent.

P. TALMEY and W. J. CREHAN, assignors to GENERAL AMERICAN TRANSPORTATION CORPORATION.
U.S. Pat. 2,941,902.

Chemical Deposition of Nickel-Boron Alloys

British Patent 836,480 claims a chemical plating solution comprising an aqueous alkaline solution of nickel or cobalt salt, a borohydride and, as a metal-sequestering agent, ammonia or an organic complex-forming compound containing one or more amino, imino carboxy or hydroxy groups. Due to the alkalinity of the solution, the sequestering agent is necessary in order to prevent the precipitation of nickel or cobalt hydroxide.

The present invention provides an improved aqueous plating solution containing nickel or cobalt ions and an amine-borane (preferably 0·015–0·2 mole/L.), from which nickel-boron or cobalt-boron alloys may be chemically deposited, in uniform layers, onto objects which have catalytic surfaces. Use of a solution having a pH of at least 3·5 ensures that the amine-borane does not decompose at a rapid rate until it comes into contact with the catalytic surface. The deposits obtained have similar characteristics to those of the deposits claimed in the parent patent, but the boron content has a wider range (1–8 per cent. boron; 99–92 per cent. nickel or cobalt). While some 5–10 per cent. of the metal may be present as crystalline nickel or cobalt, the metal is, in general, structurally unorganized and non-crystalline. Both boron and any crystalline metal are uniformly dispersed and distributed throughout the matrix.

E. I. DU PONT DE NEMOURS AND COMPANY.
Brit. Pat. 842,826.

Stripping of Nickel Electrodeposits

Electrodeposited coatings of nickel or cobalt or their alloys are stripped from the basis metal (e.g., a copper-base alloy) by immersing the plated component in a liquid bath (at a temperature ranging from ambient to boiling) of a composition consisting essentially of an ingredient selected from each of the following groups: (1) nitro-substituted aromatic compounds containing at least one NO_2 attached to a benzene ring which also carries a radical having a water-solubilizing effect on the nitro-substituted aromatic compound and water-soluble nitro-substituted aliphatic compounds and those which have a water-solubilizing group attached thereto; (2) primary and secondary amines, and tertiary amines of an alkalinity comparable to the primary and secondary amines. The combination of nitro-containing compound and amine (in a ratio ranging from 1:50 to 9:1) comprises at least 0·01 wt. per cent. of the composition.

The solution offers the advantage of improved selectivity in the reclamation of plated objects, the electrodeposit being stripped while the basis metal remains relatively unaffected.

M. WEISBERG and F. P. BUTLER, assignors to ELTEX CHEMICAL CORPORATION. *U.S. Pat.* 2,937,940.

Improved Solution for Electroless Deposition of Nickel

Addition of 0·1–10 p.p.m. of selenic acid to an aqueous electroless nickel-plating solution of the following composition increases the rate of deposition (by, it is stated, more than 50 per cent.) and improves the brightness and appearance of the deposit: nickel ion 1–100 parts by wt., an alkaline hypophosphite (the hypophosphite radical being present in 1–100 parts by wt.), sodium hydroxyacetate 5–100 parts by wt.

C. H. DE MINJER and A. BRENNER, assignors to the U.S. SECRETARY OF COMMERCE.

U.S. Pat. 2,929,742.

Production of Sintered Aluminium-containing Alloys

Sintered alloys consisting predominantly of aluminium (aluminium <50 per cent.), transition metals and/or actinides are produced by: (1) alloying the last two constituents (present either in solution in mercury or, finely distributed, in elemental form or in the form of a compound of mercury) with aluminium (present in solution in mercury) at a temperature higher than 360°C. (preferably under pressure at a temperature higher than 450°C.) and in the complete absence of air and moisture; (2) removing all traces of mercury by distillation; (3) compacting the alloy powder to the desired shape without preliminary grinding; and (4) sintering *in vacuo* or in an atmosphere free from oxygen and water vapour.

The invention is stated in the preamble to be very suitable for application to, *inter alia*, the production of permanent magnets of the following composition: nickel 28, aluminium 13–14, per cent., remainder iron; cobalt 76, manganese 11, aluminium 13, per cent.; nickel 22, aluminium 12, per cent., remainder iron; nickel 18, aluminium 6, cobalt 35, titanium 8, per cent., remainder iron.

SIEMENS-PLANIAWERKE A.G. FÜR KOHLEFABRIKATE (inventors, E. FITZER and P. GERASSIMOFF).

German Pat. 1,078,773.

Creep-Resistant S.G. Iron

Many spheroidal-graphite cast irons produced by magnesium-treatment, particularly those having a ferritic matrix, are not appreciably more creep-resistant than flake-graphite irons. According to the invention claimed, a ferritic S.G. iron with improved creep-resistance is produced by compositional modifications (the copper content is particularly important in this respect) and suitable heat-treatment.

The heat-treated ferritic cast iron contains: carbon 3–4, silicon 2·25–6, manganese 0·5–1·25, phosphorus 0·05–0·1, nickel 0·75–1·5, copper 0·35–1·1, molybdenum 0–1, per cent., and sufficient magnesium to ensure a spheroidal-graphite structure in the as-cast condition. The microstructure of the iron presents a dispersion of a finely divided discrete phase consisting of a copper-rich precipitate. The preferred heat-treatment involves annealing for 2 hours or more in the range 1650°–1800°F. (900°–980°C.) and slowly cooling to a temperature below the alpha-gamma transformation temperature.

MOND NICKEL COMPANY, LTD. *Brit. Pat.* 845,432.

Nickel-base Turbine-Blading Casting Alloy

Turbine blades, or other articles subjected in service to stress at elevated temperatures, are cast in an alloy containing: chromium 10–35, molybdenum 6–10, aluminium 4–8, niobium 0·1–5, titanium 0·1–3, boron 0·01–0·1, iron 0–25, zirconium 0–2, per cent., remainder (and at least 40 per cent.) nickel.

The alloys of the invention are characterized by high tensile strength at elevated temperature and highly satisfactory elongation properties (e.g., a tensile strength higher than 30 t.s.i. (67,200 p.s.i.: 47 kg./mm.^{2}), and an elongation of 20 per cent., at 950°C.).

MOND NICKEL COMPANY, LTD. *Brit. Pat.* 840,213.

Nickel-base High-Temperature Alloy

An improved age-hardenable high-temperature alloy falls within the following composition range: chromium 18–20, cobalt 9–12, molybdenum 9–10·7, titanium 3–3·3, aluminium 1·3–1·9, carbon 0·06–0·2, per cent., remainder nickel. The alloy may also contain boron 0·02 max., silicon 0·5 max., manganese 0·5 max., iron 5 max., per cent.

The titanium and aluminium range is stated to be critical and to result in increased strength properties, and, in sheet form, the strength/weight ratio

of the alloy is unusually high: data typifying properties of bar and sheet material are tabulated in the preamble, and optimum heat-treatments are discussed.

L. P. JAHNKE and M. A. POHLMAN, assignors to GENERAL ELECTRIC COMPANY. *U.S. Pat.* 2,943,758.
Similar to French „ 1,224,961.

Nickel-Chromium-Cobalt High-Temperature Alloys

The age-hardenable alloys to which the patent relates combine satisfactory oxidation- and corrosion-resistance with good strength properties at temperatures as high as 2000°F. (1095°C.). They may be hot-worked, and are stated to be suitable for such applications as turbine blades, exhaust valves and manifolds in internal-combustion engines, and liners for retorts and container vessels in the chemical and metallurgical industries. The results of tests carried out at 1700°F. (925°C.), under a load of 25,000 p.s.i. (11 t.s.i. : 17·5 kg./mm.²), indicate that rupture life can, under these conditions, be as high as 507 hours.

The alloys comprise (wt. per cent.): chromium 15–25, cobalt 5–30, titanium 0·5–4, aluminium 2–5, tantalum and/or niobium 1–5, tungsten 5–11, per cent., remainder nickel. The sum wt. % tungsten + 1½ × wt. % tantalum and/or niobium + 2 × wt. % aluminium + 4 × wt. % titanium = 22–30.

SIERRA METALS CORPORATION. *Brit. Pat.* 840,496.

Precipitation-Hardenable Steel with Improved Arc-Welding Characteristics

A precipitation-hardenable stainless steel, which is readily weldable by the inert-gas tungsten-arc technique, giving sound, tough and strong joints, contains (per cent.): carbon 0·1 max., chromium and nickel (in amounts delimited in an accompanying diagram), aluminium 0·75–1·5, molybdenum 6 max. (the chromium content being decreased proportionately when molybdenum is present), titanium 0·05–0·2 and/or zirconium 0·1–0·4 and/or uranium 0·3–1·0, remainder iron. Addition of titanium, zirconium and/or uranium is stated to improve the arc-welding properties of the steel.

A preferred composition comprises: carbon 0·08 max., chromium 16·9–17·65, nickel 6·75–7·5, aluminium 1·0–1·35, zirconium 0·1–0·4 (or titanium 0·05–0·2), per cent.

ARMCO INTERNATIONAL CORPORATION.
Brit. Pat. 846,140.
Similar to French „ 1,188,593.
„ „ *Canad.* „ 594,171.

Nickel-base Alloys Resistant to Hot Concentrated Sulphuric Acid

Generally, the addition of boron to a nickel alloy increases the alloy's hardness and decreases its corrosion-resistance; addition of silicon increases both hardness and corrosion-resistance. In the alloys covered by the two patents referred to below, the boron and silicon contents complement each other, to the extent that the deleterious effect of boron on corrosion-resistance is offset by the beneficial effect, in this respect, of the silicon: the two elements confer significantly improved hardness and durability without an accompanying excessive brittleness.

Patent 2,938,786 covers alloys falling within the following limits of composition: chromium 19–26, molybdenum 5–9, copper 4–7, silicon 1·5–7·5, boron 0·025–0·55, iron 10 max., manganese 1·5 max., carbon 0·3 max., per cent., remainder nickel. The silicon and boron contents are so related that the hardness of a specific alloy may be pre-determined: the invention thus makes available a series of alloys exhibiting high hardness (without brittleness) and good corrosion-resistance (in both oxidizing and reducing media), and possessing good mechanical strength, wear-resistance, resistance to galling, non-sparking qualities, and satisfactory machinability and weldability.

Data tabulated illustrate the resistance of such alloys to various concentrations of sulphuric acid. In 93 per cent. sulphuric acid, a corrosion rate of less than 0·02 in. (0·5 mm.) per year is obtainable at temperatures up to 100°C. Hardness ranges from 200 to 400 Brinell and strength from 70,000 to 80,000 p.s.i. (31–36 t.s.i.; 49–56 kg./mm.²).

T. E. JOHNSON, assignor to STAINLESS FOUNDRY AND ENGINEERING, INC. *U.S. Pat.* 2,928,786.

The silicon and boron contents of the nickel-base alloys covered by *Patent* 2,938,787 may be adjusted so as to enable pre-determination of the hardness of a given alloy, and the high hardness of such alloys (like that of the alloys referred to in the preceding abstract) is unassociated with brittleness, and is supplemented by high resistance to corrosion by oxidizing or reducing media.

Data on corrosion behaviour in sulphuric acid indicate that corrosion rates in 93 per cent. acid are less than the maximum rate tolerable in industrial usage (i.e., 0·02 in./year). Tensile strength ranges from 65,000 to 75,000 p.s.i. (29–33·5 t.s.i.; 45·5–53 kg./mm.²) and hardness values range from 200 to 400 Brinell.

The following limits of composition are claimed: chromium 26–30, molybdenum 7·5–9, copper 4–6·5, silicon 1·5–6·5, boron 0·025–0·55, iron 3·5 max., manganese 1·6 max., titanium 0·25 max., carbon 0·12 max., per cent., remainder nickel.

W. K. BOYD, M. E. LANGSTON and T. E. JOHNSON, assignors to STAINLESS FOUNDRY AND ENGINEERING INC. *U.S. Pat.* 2,938,787.

Improved Nickel-containing Spray-welding Alloys

A disadvantage associated with the self-fluxing alloys commonly applied as overlays by the 'spray-welding' technique is the occasional occurrence, after fusion treatment, of small isolated pores in the coating. The occurrence of such pores, which are deleterious

since they are frequently uncovered during finishing or grinding operations, is, according to the claims of the patent, prevented by incorporating, in any conventional spray-welding powder of the self-fluxing type (e.g., nickel-base, cobalt-base, or nickel-cobalt-base alloys), at least 0·2 wt. per cent. (preferably 0·2–2 wt. per cent.) of aluminium.

METALLIZING ENGINEERING COMPANY, INC.

Brit. Pat. 843,423.
Similar to French „ 1,209,669.
„ „ „ „ 2,936,229.

Welding Rod for Hard-Facing

A principal object of the invention is the provision of a welding rod of hard-facing composition having a novel structure stated to facilitate deposition of effective abrasion- and wear-resistant overlays at relatively low temperatures and which may be stored over long periods without deterioration.

A tubular mould is firmly packed with small hard particles (such as carbides) and then heated to the melting temperature of the matrix alloy. The molten matrix alloy is fed into the packed mould, seeps through, and thoroughly wets, the pre-positioned hard particles, and then settles to the bottom of the mould to form a composite rod comprising hard particles completely enveloped in the matrix alloy. The matrix alloy consists preferably of a copper-nickel-zinc alloy, aluminium-bronze (aluminium 8–10 per cent.), or a nickel-base alloy containing nickel 60–80, chromium 10–20, boron 2–6, silicon 0·5–6, per cent. Carbides of tungsten, boron, vanadium and silicon are claimed as hard-particle constituents. The welding rod may include a flux and a copper-lithium alloy (which acts as a deoxidizer and improves the fluidity of the matrix material).

J. QUAAS, assignor to EUTECTIC WELDING ALLOYS CORPORATION. *Canad. Pat.* 589,606.

Nickel-base High-Temperature Brazing Alloys

An improved nickel-base brazing alloy, which starts to melt at about 1980°F. (1080°C.) and whose use results in a sound ductile joint suitable for service at temperatures up to the region of 2300°F. (1260°C.), comprises: silicon 1·5–2·4, boron 0·5–1·8, wt. per cent., remainder nickel. The fusing and brazing temperatures of the alloy are within the range in which both solid and liquid phases exist in equilibrium: a principal advantage therefore is that, unlike conventional brazing alloys, it need not be heated during brazing to a temperature at which it would be entirely liquid.

The patent includes a revision of the nickel-rich end of the nickel-boron equilibrium diagram.

GENERAL ELECTRIC COMPANY. *Brit. Pat.* 843,386.

Nickel-Silicon-Boron-Gold Brazing Alloys

In *U.S. Pats.* 2,743,177 and 2,755,183 the inventor has claimed a series of nickel-silicon-boron brazing alloys consisting essentially of silicon 2·5–5·5, boron 0·75–5·25, per cent., remainder nickel. One of the characteristics of these alloys is that, whilst the most suitable compositions are hard and relatively brittle, there is a tendency for the alloys, when used for brazing purposes, to dissolve the surfaces of the parts which are being joined, an effect which reduces the hardness of the material in the joint, and results in a ductile joint. In many cases, however, dissolution of the basis metal cannot be tolerated. According to the claims of the present patent, a brazing alloy of the following composition is stated to be inherently ductile and tough, and yet satisfactorily to wet the surfaces to be joined without producing weak structures: manganese 10–30, gold 2·5–20, silicon 0·5–3·5, boron 0·5–3 (and, preferably, cobalt 0–20, chromium 0–10, iron 0–10), per cent., remainder nickel. The boron content has been lowered to achieve the required aim; the gold content is intended to reduce the high melting point associated with the low boron content and to impart ductility to the alloy; addition of cobalt prevents basis-metal erosion and increases strength and ductility.

A. T. CAPE, assignor to COAST METALS, INC.

U.S. Pat. 2,944,891.

Electrode for Production of Crack-Free Austenitic Stainless-Steel Welds

A welding electrode claimed to produce a non-magnetic (austenitic) crack-free weld is of the following composition: carbon 0·3 max., silicon 0–3, chromium 12–26, nickel 9–22, manganese 8·5–20, molybdenum 0–4, copper 0–5, niobium+tantalum 0–1·5, titanium 0–1·5, per cent. The chromium, nickel and molybdenum contents are selected in accordance with one of five given ranges.

A preferred composition consists of: carbon 0·08 max., chromium 17–19, nickel 9–12, manganese 8·5–20, per cent., niobium+tantalum 10×C.

ARMCO INTERNATIONAL CORPORATION.

Brit. Pat. 830,608.
Similar to U.S. „ 2,894,833.

Copper-Palladium-Nickel and Copper-Palladium-Nickel-Manganese Brazing Alloys

The two patents cover brazing alloys which, in their application to the fabrication of components intended for service at temperatures of 550°C. and above, offer advantages over those previously available.

The alloys are particularly suitable for use in brazing those alloys which tend to form coherent, tenacious and refractory surface oxide films. The clearance between the parts to be joined is not critical for the production of a sound joint, and the alloys are stated to be better adapted to vacuum brazing than previous brazing alloys because, at their flow temperatures, they exhibit less tendency to evaporate.

British Patent 838,949 covers a brazing alloy containing copper 10–60, nickel 10–50, manganese 1–30, per cent., remainder (and at least 10 per cent. palladium.

British Patent 838,951 claims a copper-palladium-nickel alloy of a composition falling within a range delimited in the patent in a ternary diagram.

MOND NICKEL COMPANY, LTD. (inventor, D. W. RHYS).
Brit. Pat. 838,949.
„ „ 838,951.

Nickel-Manganese-Silicon-base High-Temperature Brazing Alloys

A high-temperature brazing alloy, stated to produce (in air, at compatible temperatures, in a relatively short time, and without deleterious alloying with the basis metals) sound strong corrosion-resistant joints in ferrous and non-ferrous materials, contains nickel 35–91 (up to 90 per cent. of which may be replaced by cobalt), manganese 0·5–60, silicon 1–8, per cent., and, optionally, one or more of the following elements up to the percentage stated: boron 3, chromium 10, iron 20, tungsten 3, molybdenum 5, titanium 5, niobium 5, carbon 1, germanium 10, copper 10, aluminium 2, rare-earth metals 0·5, per cent.

The alloys are produced by roasting small pieces of the nickel (or nickel-cobalt mixture) to drive off occluded gases, heating the roasted metal with manganese at 2000°–2300°F. (1095°–1260°C.) until a homogeneous melt is obtained, adding the other constituents and holding at temperature until the melt is homogeneous, and, where desired, adding the rare-earth-metal content shortly before pouring.

SOLAR AIRCRAFT COMPANY (inventors, G. D. CREMER and F. J. FILIPPI). *Brit. Pat.* 838,516.

Brazing of Titanium and Zirconium with a Cupro-Nickel Alloy

Titanium, zirconium or titanium- or zirconium-base alloys are brazed in an inert-gas atmosphere, using (preferably in the form of foil 0·0005–0·0025 in. thick) a cupro-nickel alloy containing at least 50 (preferably 80) wt. per cent. of copper. Where the parts to be joined are of titanium or titanium base, brazing is effected at a temperature in the range 960°–1100°C. (preferably 1000°–1050°C.).

IMPERIAL CHEMICAL INDUSTRIES, LTD. and E. A. TAYLOR.
Brit. Pat. 833,758.
Similar to French „ 1,189,194.

Copper-Manganese-Aluminium-base Alloy Resistant to De-aluminification

A single-phase copper-base alloy containing manganese 5–20, aluminium 1·5–7, nickel 6 max., arsenic and/or antimony 0·01–0·2, per cent., intended for use primarily in the wrought form, possesses good corrosion-resistance and good cold-working, mechanical, welding and elevated-temperature properties. The alloy may also contain iron 5 max., tin 3 max., phosphorus 0·2 max. (and less than the content of arsenic and/or antimony), per cent.

The addition of small amounts of arsenic and antimony are stated to inhibit de-aluminification in acid and salt solutions, an effect which is enhanced by the presence of nickel.

J. STONE AND COMPANY (CHARLTON), LTD. (inventors, R. J. M. PAYNE and A. W. O. WEBB).
Brit. Pat. 835,477.
Similar to South African „ 4532/59.

Nickel-Chromium-Boron Addition Alloy for Use in the Production of Sintered Stainless Steels

Under the claims of the patent, a powdered pre-alloy of the following composition is added to the powder charge used in the production of sintered steels: chromium 15–20, boron 3–5, silicon 5 max., iron 3 max., carbon 0·5 max., per cent., remainder (70–75 per cent.) nickel. The invention is based on the finding that incorporation of the ternary nickel-chromium-boron alloy into the powder mixture prior to sintering (particularly in the case of steels containing, alone or in combination, chromium, nickel, molybdenum and manganese) has a beneficial effect on density, strength and toughness.

Preferably the pre-alloy contains nickel 72, chromium 18, boron 4, silicon 3, iron 2, carbon 0·3, per cent., and is added, in amounts of from 2 to 10 per cent., to steel powder charges comprising chromium 16–18, nickel 7–9, per cent.; chromium 17–19, nickel 10–12, molybdenum 2–3, per cent.; or chromium 18–20, manganese 8–10, per cent.

DEUTSCHE EDELSTAHLWERKE A.G. (inventors, W. HOTOP and F. BENESOVSKY). *German Pat.* 1,077,235.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Trade Marks*.

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